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AN

AGRICULTURAL PRIMER,

FOR USE IN

INDIAN ELEMENTARY SCHOOLS OR CLASSES.

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INTRODUCTION.

The object of these lessons is to point out some of the chief principles on which the various operations of agriculture depend for their success. It is not intended, except in a very few instances, to give descriptions of the operations themselves; and in treating of the facts on which they depend, it has been endeavoured to use a simple language as possible, in order that they may be easily understood by persons who have no knowledge of the terms used in scientific discussions.

A distinction is to be made between a knowledge of the best methods of growing the different crops and a knowledge of the reasons why these methods are the best. The former is in India usually gained by experience, very few people knowing the reasons of the various agricultural operations they practise, but being content with knowing that, as a matter of fact, they and their fathers have always found them succeed. But none the less is a knowledge of the reasons necessary for good agriculture. It takes a long time to find out improvements in agriculture by experiment alone, while, if the reasons on which agricultural processes are founded are properly understood, improvements often suggest themselves without any need of experiment whatever. For instance, one of the operations of agriculture is to manure land, and people do it because they know that manure improves their crops, although they do not understand in what way it improves them. But when it is understood that manures improve crops because the crops feed on them exactly as we grow by eating our food, we can discover new kinds of manure which never would have been used otherwise. It is known what are the different things a plant needs for its food; it is known how many of them it

can gain from the ground for itself: and manures are in Europe now manufactured which will exactly supply the missing things, without wasting substances of which the plant has no need.

A knowledge of the *reasons* of agriculture is therefore necessary for any large improvement, and, perhaps, it is because these reasons are not generally known that agriculture in India seems to have made little or no progress, but to be in the same state now as it was generations and generations ago.

AGRICULTURAL PRIMER.

Lesson I.

The similarity between the growth of animals and plants.

Agriculture is the art of raising field plants from the ground, so it is with *plants* that we are chiefly concerned in treating of the principles of agricultnre.

There is a very great difference between a plant and an animal, but perhaps not more than between some animals and others. The difference, for instance, between an elephant and the tiny creatures which swim about in dirty water (so small as scarcely to be seen with the eye) is almost as great as between the elephant and a tree. A distinction which people often make is that animals can move while plants cannot move; but there are many kinds of small animals living in water which are attached to sticks or stones by a kind of root and cannot move themselves. On the other hand, some kinds of plants, while very young, are able to move about in water from one place to another, being covered with little hairs which are in constant quick motion and push the plant through the water just as a fish is pushed along by its fins. A great many plants are able to move some portions of themselves. Some flowers open and shut regularly at different hours

of the day, while there is a kind of very small babul (the *chui-mui)* which, if touched, instantly closes its leaves just as if it were hurt or offended. Although, then, there are great differences between the common sorts of plants and animals, yet it is extremely difficult to make a rule which shall exactly distinguish between them. Both are alike in *being alive*—that is to say, in being born, existing for a limited time, and dying again ; and both grow by taking in food from the outside and altering it till it becomes in substance like their own bodies.

Few people will deny that the son of respectable parents, well-fed, well-clothed and properly taught, has a better chance of becoming an honest, industrious man than the son of thieves or vagabonds, half-starved and relying for subsistence on the wickedness which is the sole lesson life has taught him. In exactly the same way a plant sprung from good seed, sown in well-manured, well-watered, and well-ploughed land, has far more chance of bearing plentiful and good grain than one sprung from bad seed and left to shift for itself on barren, unmanured, and dry land. The chief requisites for a good crop are, then, good seed (which is compared to the parentage of a boy), good manure and sufficient water (which is compared to his food), and good cultivation (which answers to his education) ; and these three requisites will be separately noticed in these lessons.

From what was said at the commencement of this lesson, it follows that the comparison between the bringing up of a boy and a plant is not so fanciful as it seems at first sight. Plants, like animals, live and grow by the food they take in,

are influenced for good or bad by their surroundings, and inherit the qualities of the seed from which they spring. But since it will be impossible to understand this or to comprehend many of the chief principles of agriculture without knowing something of the structure and life of a plant, these will form the subject of the next lessons.

Lesson II.

The different parts of a plant.

Every ordinary field plant may be considered as made up of two parts: one growing downwards into the soil, called the root; and the other, growing upwards towards the light, called the stem. The root and stem are as a rule very different in appearance, and can be easily distinguished from one another, but in their internal structure they are very much alike. Most of you have probably only thought of roots or stems as consisting of the same kind of substance throughout, but in reality they are made up in the most wonderful manner of millions of little pipes, bags, and fibres packed tightly together and so small that they can scarcely be seen at all without a magnifying glass. If you cut open an orange, you will see that the inside of the fruit is made up of a number of little pointed bags placed side by side, each consisting of a covering of thin skin filled with the sweet juice which makes the orange a favourite fruit. Now it is important to remember that every part of a plant is made up of little bags, something like

those of the orange, only very much smaller. The way this was found out was by the magnifying glass, which is a piece of glass so shaped as to make things, when examined through it, look much bigger than they do to the eye. This piece of glass, instead of being flat on both sides, is rounded, and it is this which causes things seen through it to seem bigger than they really are. A drop of water will act in just the same way, and if a drop of water be placed on a leaf and be looked through sideways, it will be noticed that it makes the small hairs on the leaf look much bigger than they generally do. This is because the drop is rounded in its shape like a magnifying glass. By means of these magnifying glasses a flea can be made to look as large as a mouse, and its mouth, eyes, and even teeth, be seen as easily as those of a mouse. When plants were looked at in this way, it was seen that they were made up of little bags, just as an orange is; each bag in young plants being filled with liquid. If a piece of plantain stem be cut across and looked at, a great number of tiny little holes will be seen in it. These are the ends of little tubes which run up and down the stem, and which are believed to be merely rows of bags with their ends knocked out. The green substance of which the plantain stem is composed is made of little bags shaped like bricks and fitted one to another like a mass of masonry, through which these little tubes run like water-pipes. All young and green plants are composed, like the plantain, of these little bags, consisting of an extremely thin skin filled with liquid, just as we saw in the orange.

The skin is so thin that it allows the liquid to soak through from one bag to another. As the bags grow older their skins get thickened by the formation of an inner and harder lining, and ordinary wood is composed of bags thickened in this way. Both root and stem are composed of these little bags (called *cells*), with tubes running up and down amongst them ; but though the root and stem are therefore much the same in internal structure, the work they have to perform is very different.

The work of the *root* is, generally speaking, two-fold : it keeps the plant firm in its place, just as an anchor holds a boat, and it sucks up from the ground the water and substances contained in water on which the plant feeds. It thus answers to the feet and mouth of an animal. The stem, on the other hand, supports the leaves and flowers and exposes them properly to the wind, sun, and rain. The water and watery substances sucked up by the root pass up through the stem to the leaves and flowers.

The chief parts of every ordinary plant are the root, stem, leaves, and flowers, each of which will will now be noticed in turn.

The Root.

Roots may be thrown into two classes. One kind of root possesses a main trunk continued downwards from the stem, from which side-roots branch off, just as branches do, from the stem. The other kind consists in a bunch of fibres, which break out in a sort of tuft from the bottom of the stem and spread in a so-called "crown" all

round it. The former are called *tap-roots*, the latter *crown-roots*. These, like the babul, ním, or tamarind, have tap-roots, so also have the carrot, cabbage, arhar, and cotton plant. Palms have crown-roots, and so have all plants of the grass kind, such as wheat, barley, jowar, and maize. Tap-roots often grow downwards to a great depth, those of some English trees having been found 95 feet deep. Plants with such deep roots keep green, whether the upper soil remains moist or hot, since their roots reach the lower supplies of water from which the wells are filled. An example of this is the plant callod *baisurai*, which grows in large quantities in corn-fields in the Aligarh district. It has a long root like the lash of a whip, which grows down to a great depth, and the plant is thus able to keep green in the months of May and June, when all other small plants become quite dried up, unless frequently watered. The thin fibres of which *crown-roots* are composed are not so well able to force their way into the soil as *tap-roots*. Instead of driving their way straight down into the ground as tap-roots do, they spread themselves out round the plant near the surface : and hence plants with *crown*-roots are dependent for their food and moisture on the surface soil, while plants with *tap*-roots are able to procure food and moisture from a greater depth. It is therefore far more important to have the surface soil well cultivated for a *crown*-rooted plant than for a *tap*-rooted one. The finer the soil is powdered, the better it retains moisture and the easier it becomes for the plant roots to draw their food from it. Loose friable ·· will, as is well known, keep moist when hard

caked soil dries up at once. This is the reason why so much more care is taken in ploughing the ground for *crown*-rooted plants, such as wheat and barley, than for *tap*-rooted plants, such as indigo and gram. It is not uncommon for cultivators to plough their land twelve or even fifteen times for wheat, while one or two ploughings are held sufficient for gram. If the surface soil were not in proper order, the wheat roots would be altogether unable to procure the food and moisture which the plants require; while the gram roots, by sinking deeper into the soil, have a far larger area at their disposal and are therefore more independent of the surface soil.

It has been mentioned that the roots at once support the plant firm in its place and also act as its mouth, sucking up water from the soil. The parts of the root which suck water in this way are not the thicker and larger portions, but the tiny white hairs with which the young tops of the root branches are covered. If in transplanting a plant these tops are broken off it will die, although otherwise the roots are unhurt. If a wheat plant be pulled up and the roots well shaken, it will be seen that the tops of the roots are covered with a fine coating of earth which does not drop off with the shaking. This earth keeps in its place because it is held by these little hairs, which cling closely to it and suck up the moisture and food substances it contains. The roots can suck in this way with great strength, especially in the spring, when they are most active. The juice is forced upwards from the root through the stem, passing from cell to cell through the thin skin which separates them. If

the stem of a vine be cut in the spring, the juice will pour out of the wound in a stream.

Most roots grow underground beneath the surfoce of the soil; in some cases, however, they grow in water or even in the air. The roots of the singhara live altogether in water, while the bargad tree and the maize plant have roots which grow out into the air.

Another work which some roots do, and which has not yet been mentioned, is to act as a storehouse for the plant and collect and store food in one year to be used up in the next. This is the reason why the roots of the carrot and beat are so large. In the first year they collect and store food, which the plant uses up in the second year, when it flowers. We dig up and eat the roots when the food is stored in them, and before the plants has time to use it.

There are certain underground stems which are very like roots; so like, indeed, that most people call them roots. These are the potato, yam, and other plants of the same sort. The rounded bulbs which we eat are not roots, but thickened underground stems, and may be distinguished from roots by their having buds, which true roots ordinarily never produce.

Lesson III.

The different parts of the plant.

The Stem.

The stem of a plant has to perform two duties; it has, firstly, to support the leaves and flowers and allow them to obtain as much sun and air as they

need ; and, secondly, it has to act as a channel of communication between the root and the leaves and allow the liquid which the root sucks up to pass up to the leaves and flowers. In young plants the stem is usually green and tender, but in older plants and trees it becomes very hard, since it has often a great weight of branches to support. It is originally made up of the little bags (or *cells*) described in the last Lesson, but these become hardened by the formation of a woody layer inside them which in time fills them, so that they become soiled. But new cells, either round the outside, just beneath the bark, or nearer the middle of the stem, keep on forming, and they act as water-carriers between the root and the leaves, allowing the liquid to soak up through their delicate skins.

But the stem is not entirely composed of these cells ; little tubes and fibres run up and down, and these tubes and fibres are generally collected into bundles, there being a bundle to each bud on the stem. In some plants (the grasses, plantains, palms) these bundles run down every part of the stem, the centre as well as nearer the outside. In other plants (like the arhar, mango, and cotton plant) they are all confined to the outside of the stem, just beneath the bark. They serve to keep up a connection between the buds and root, and since every branch is derived from a bud as well as the leaves and flowers, their use is very important. The shape of a tree depends on the manner in which the buds come on the stem. If the buds grow out in rings at certain places up the stem, the branches will be in rings too, like the

semul. If the buds grow out alternately, the branches will be alternate also : and thus the shape of trees can be much altered by pinching off some of the buds when they first grow out. If a bud be deprived of the proper amount of light and air, it is killed ; and so it happens that trees become distorted when they grow close together in a forest, and their branches are often all confined to the top, instead of growing out all down the trunk, since the shade kills the buds which are lower down. For the same reason, crops which are very thickly sown grow very tall and have few branches. In Europe flax is grown for its fibre and not for its seed, and it is there sown very thickly, so as to make the stems longer and less branched than they are in India ; for better fibre is got from a long straight stem than from a short and much branched one. In the same way, if a field of wheat be very thinly sown, each seed, instead of giving one or two stems, will give seven or eight, which spreads out into a large tuft ; and in this way as much grain can be got from one seed as from three when they are thickly sown, although the total produce of the field may be somewhat less.

Flax fibre has been mentioned above. This is obtained from the outside rind of the flax plant, called the bark. This bark is found in most trees, to which it is useful as a sort of coat. Outside it is hard and rough, but inside it is very soft and very tough. It is made up of little cells like the rest of the plant, but the cells are longer and thinner, and this makes the bark tougher and more pliable than any other part of the plant.

Hemp (bhang), sanái, and patsan are all obtained from the *bark* of the plants they come from.

Although stems as a rule differ from roots in growing upwards towards the light, yet it must be remembered that the stems or part of the stems of some plants grow underground, just like roots, from which they can scarcely be distinguished. The potato and yam have already been mentioned as being really *stems* and not roots, although they grow beneath the surface of the soil.

The Leaves.

Just as the root answers to the *mouth* of animals through which nourishment is taken in, so do the leaves answer to the stomach in which this nourishment is digested. If a glass-shade be placed over a plant, such as the cabbage, it will be seen after a short time to become dim inside with vapour, and after a little while the vapour will form drops of water on its sides, which slowly roll down to the ground when too heavy to keep their places. This vapour is sent off by the leaves of the plant, and in warm weather is always leaving it. It has been calculated that in three months a single plant of maize sends out water to the amount of 36 times its own weight. Like the buds, each leaf is the end of one of the bundles of little tubes which run down the stem to the root. The leaf itself is made up of two or three layers of flattish cells covered by a thin skin, which in many leaves can be scratched up by the finger-nail and pulled off. All over this skin are little openings or *pores*, like the pores in our skins through which we perspire. They are shaped

something like little mouths, the two lips being formed by two spindle-shaped cells placed alongside one another, but only joined by their ends, so as to leave an opening between them. It is through these openings that the vapour escapes.

These little pores are extremely small and are in some plants found in astonishing numbers. In the case of many trees each leaf has as many as 1,00,000 of these little pores scattered over its upper and under surfaces. They are chiefly confined to the under sides of leaves, except in water plants, like the lotus (kamal), in which case they are on the upper surface only.

It is in the leaves that the green colour peculiar to plants is chiefly noticeable. It is caused by a vast number of little green balls inside the cells of which the leaf is composed, and, as will be seen further on, are not altogether for ornament, but perform a very important part in the life of the plant. Leaves occur of any shade of green, and in some cases red or brown. The young mango leaf is often of a beautiful purple tinge. In these cases the balls of colouring matter are red or purple instead of green.

Lesson IV.

The different parts of a plant.

The Flower.

We next come to the most important part of a plant—the flower. It is by far the most difficult portion of the plant to understand properly, and to make it easier I take as an example the flower of the cotton. If possible, it will be well for the

readers to have cotton flowers in their hands at the time they are reading this. It will also make this explanation clearer if at the same time are picked four pieces of cotton plant—one with a bud not yet opened, another with a fully opened flower, a third with an unripe fruit, and a fourth with the fruit burst open, showing the cotton pods inside.

Take first of all the bud. You will see that around the bottom of the flower there are four small green leaves, which make a kind of case to protect it. These are not, properly speaking, part of the flower, but are merely leaves which serve to cover it while in bud. All flowers do not have them.

Now pull off these four leaves, and inside them, surrounding the bottom of what is generally called the flower, you will see a little cup of thin greenish yellow skin specked with black. This is callled the *cup* and is a part of the flower-head. Most flowers have it. It is sometimes divided up into separate leaves or toothed more or less deeply. In the cotton flower it forms a little cup with the edge even all round, and it is from this shape that it is generally known as the *flower-cup*.

Under the *cup* there are the five large yellow leaves which form the bright yellow flower. In the bud these are curled and twisted round one another, and the full opened flower, which was picked, had now better been taken, since this will show the shape of these yellow leaves best. You will see that the greater part is of a pale yellow colour, deepening to red on the inside round the bottom. What is supposed to be the use of this bright colouring will be noticed further on.

Inside these yellow leaves again you will see a kind of small pillar covered with little yellow knobs, from the top of which protrudes a knob of different shape and very much larger than the others. Pull off the five yellow flower leaves and split up the centre pillar with your finger-nail. You will see that the little yellow knobs all come off together, being fastened to a strip of whitish coloured skin. This white skin forms a tube round another thinner pillar inside it, and you will see that the large top knob belongs to this second pillar and remains in its place when all the small knobs have been pulled off together with the skin they are fastened to. The inside leads down to a roundish mass, which is the unripe young cotton pod.

We have then divided our flower into the following five parts :—

(1) The four outside green leaves.

(2) The little yellow spotted *cup* inside them.

(3) The five large yellow and red flower leaves, called the *flower-crown.*

(4) A tube of white skin covered with little yellow knobs (*the flower-threads*).

(5) A pillar inside this tube, bearing at the top a largish knob, and at the bottom joined to the young cotton pod (*the flower-column*).

Now the first three of these parts are ordinarily only intended as a protection for the last two, which are the two essential or necessary parts of the flower. The use of the flower is to develope the seed, and the seed is developed by these two last-mentioned portions.

I take first of all the fourth part,—the white skin-tube covered with little knobs. Each of these little knobs is a small box filled with yellow dust. They burst when the flower opens, and the dust is scattered about. If you open a fresh flower bud, you will see all the little boxes as they appear before bursting. The skin-tube to which all these little knobs are fastened is really made of their *stalks*, which in the cotton flower are thus joined together.

In other flowers, such as the mango, each little knob is carried by a separate stalk of its own, and there is no tube made round the central pillar. Each stalk, with its knob, is called a *flower-thread*.

Now look at the fifth part—the central pillar, which is the only part which you have not pulled off from the stalk. You will see that it consists of a white column bearing a long knob at the upper end and fastened to the small cotton pod at the lower end. This pillar may be called the *flower-column*. The knob at the top is covered with a sticky substance, and, if the flower has been opened some time before you picked it and you look closely, you will see some yellow dust sticking to the knob. This is the dust which has come off the little *flower-threads* out of the little yellow boxes on the tube which surrounds the central pillar. This dust is most important, for, unless some of it falls on the sticky knob of the *flower-column*, the flower will bear no fruit. The *flower-column* is useless without the *flower-threads* and the *threads* without the *column*. Why the contract of this dust is necessary will be explained further on ; but it has

been well proved that if the column of the cotton plant be carefully covered over, so that no dust can get to it from the threads, then the young pod at the bottom withers up and dies without growing larger. When, on the other hand, the dust is allowed to fall on to the top of the column, the seed grows to its usual size and bears cotton as usual.

In order to see how the cotton pod grows, take the third piece of cotton plant which was picked—that, namely, bearing the unopened cotton pod. You will see that the yellow leaves of the *flower-crown* and the *flower-threads* have all faded and dropped off—their work accomplished.

At the top of the pod may be seen the withered remains of the *column*. The little *flower-cup* and the outside green leaves are still in their places, but looking rather withered. So we see that when once the flower has opened and the dust from the *flower-threads* reached the top of the column, all the parts of the flower begin to die off except the seed-pod, which goes on growing.

Cut open the seed-pod across the middle ; you will see that it is divided by partitions into compartments, in each of which there are several seeds. The seeds are packed in the soft cotton, which, when the pods burst open, dries, swells out, and is ready for picking. It is a curious fact that, though cotton looks like a collection of soft hairs, it really consists of the same *cells* which have been so often mentioned before, merely differing from other cells in being extremely long and tenacious.

Lesson V.

The different parts of a plant.

The Flower—(continued).

The cotton flower was chosen as the example for the preceding lesson not because it is the easiest to understand, but because it is one of the easiest flowers for you to obtain ; and unless you have a flower in your hand while you read the description, it will be very difficult to you to understand what is meant. You will find that each other kind of flower differs from the cotton flower in colour, shape or size ; the differences in shape being frequently caused by the various parts of the flower being joined instead of separate. A perfectly regular flower would have the leaves of its *cup* and *crown*, the stalks of its *threads*, and the compartments of its *seed-pod* all separate, and the number of the leaves of the cup and crown of the threads and of the seed compartments should also correspond. But in the cotton flower we have found the cup leaves joined so as to make a kind of collar, and the thread stalks joined into a tube, the knobs being very numerous. So in the arhar flower the *crown* leaves are curiously joined and shaped so as to look something like a butterfly, and in the til flower they are joined into a little pink tube.

Another point of difference is this : in the cotton plant the flowers are large and each stalk only bears one or two, so that they are easily distinguished. The mango, on the other hand, has hundreds of little flowers on one stalk ; so has the corander and carrot ; while some plants, such as

the marigold, have the top of the stalk flattened out and crowds of little flowers squatting on it, those on the rim of the circle being much larger and flatter than those in the middle. Wheat, barley, and jowar have their little green flowers arranged thickly on the edge of the stalk; and, indeed, in the grasses it would be hard to recognise the flowers were it not for the little yellow boxes of the flower-threads which hang from them, and for the grain which when ripe takes their place.

But, however much flowers may differ in shape, it is important to remember that to ripen seed they must have flower-threads and must have columns of some sort or other, though it is a curious fact that in some cases the flower-threads are in one set of flowers and the columns in another set, as is the case with maize. The blossoms at the top of the maize stalk contain flower-threads, while the *buttas* below hold the columns and seed-pods which ripen into grain. Unless some of the dust from the thread-blossoms falls on the column-blossoms the plants will produce no seed, and thus it has sometimes been found advisable to shake the maize plants, to assist in this falling down of the dust on to the delicate hair-like columns of the *buttas*, In some cases, as for instance with some kinds of cucumber (*karela* and *situphal*), the thread-bearing flowers are even on different plants from the column-bearing flowers. As a rule, however, threads and columns are both in the same flower, and the dust can easily either fall on to the columns or be blown or shaken by the wind on to them. But in some cases the threads are so placed that the dust cannot reach the columns in this way, and people were for some

time puzzled as to how flowers like this ripened seed. It has now been proved that the insects which visit flowers brush their bodies against the threads and so get covered with the dust, and then crawling over the column, in search of honey, carry the dust on to it. It must not be supposed that the bees, flies, and butterflies that do this service for flowers intend to do it or visit the flowers for this purpose They go to the flowers for their honey, and, while sucking the honey, carry the dust from the threads on to the columns. Perhaps this is the reason why flowers have honey at all to tempt the insects to visit them.

The bright colours of flowers are also thought to help them, since they attract insects in hope of honey, whether there be honey for them or not.

Even in the case of plants which are so made that the thread dust *can* reach the column of itself, insects do much good, as it has been shown that it is a bad thing for a flower to use its own dust, and that to get good seed the dust should be brought from another flower of the same kind. If the flowers of the common pea be tied up in bags of muslin, so that insects cannot reach them, it has been found that they bear very little seed. Any one who has watched the bees over the flowers of a pea-field, and noted how they travel from one flower to another, will see how well they effect this exchange.

To go shortly over what has been said. The object of a flower is to ripen seed. In order to ripen seed it is necessary that dust from the flower-

thread should reach the top of the column. The shape, size, and colour of the flower-cup and crown are suited to bring about this in different ways, either by letting the dust fall on the column or be blown or shaken on to it, or transferred by the help of insects.

Lesson VI.

Plants, like animals, grow by feeding.

The different parts of a plant having been described, we shall now be better able to compare the way in which a plant lives with the way in which an animal lives.

It was said before that there were many points of great resemblance between them, and the raising of a plant from seed on cultivated land was compared to the rearing and education of a child. These similarities will be even more plainly seen when we have described the various duties which the different parts of a plant perform and compare them with those performed by different parts of an animal.

Just as an animal is only able to live and grow by taking in food, so also without food plants immediately wither and die. But there is a very important difference between animals and plants both in the character of the food which is used and in the manner in which it is taken in. Animals can only live on vegetable or animal food: they cannot subsist on minerals, such as stone, earth, sulphur, or iron. But plants live almost entirely on minerals. An animal again receives the whole of its food, either as a solid or liquid,

through its mouth ; while a plant receives its food partly as a liquid through its roots and partly, extraordinary as it may seem, as a gas through its leaves.

The plant roots suck up from the ground the water which is contained in the earth surrounding them, and, together with the water, absorb a number of other very important substances which are dissolved in it. This liquid slowly works its way up the stem into the leaves, where it is exposed to the light, and the surplus water being got rid of in the shape of vapour, the remainder is digested much as an animal digests in its stomach the food it has eaten. When properly digested, the liquid returns from the leaves to the tubes and cells of the stem, going all over the plant to the different portions which need nourishment. But the food taken in by the plant roots is not so important as that taken in by the leaves. Of the different substances of which a plant is composed, the most important exist in the air in the shape of a gas or vapour, mixed with another gas. The leaves absorb this gas-mixture, and under the influence of sunlight the two gases are separated, one thrown out again by itself and the other appropriated in a solid form. Curious though it seems, yet it is true that the solid parts of plants are largely composed of a substance which is sometimes a gas and at other times a solid, and which when a gas cannot be seen or felt ; and it is still more wonderful that the principal way in which this substance becomes a gas in the air, so that the plant-leaves can absorb it, is by the decomposition or decaying of animal or vegetable bodies. It is also given off in great

quantities in the breath of animals. The gas is very poisonous for people to breathe, and that is the reason why it is so unhealthy for a number of people to sleep or live together in a small closed room, since the breath they breathe out is all strongly tainted with this gas, which in time infects the air of the whole room. We thus see that one of the chief foods of plants is a gas which animals reject as poisonous.

It may be thought impossible that a gas would be fixed in a leaf and become a solid body like wood ; but it has been now proved that each of the primary substances of which the objects in this world are composed may exist in any one of three forms—solid, liquid, and gaseous. A good instance of this is water, which is generally liquid, but may be solid in the form of ice, or, when heated above the boiling point, gaseous in the form of steam. So also lead and other metals, which are some of the most compact of solids, can be made into liquids by being greatly heated ; though to make them gas requires more heat than can generally be applied.

The food of a plant may be therefore considered as being of three kinds : firstly, *gases* which the leaves absorb from the air ; secondly, *water* which the roots absorb from the soil ; and thirdly, *mineral substances* which are absorbed by the roots with the water. If we consider an ordinary plant to be made up of 100 parts, then 48 of these parts will be composed of gases absorbed from the air, 46 parts of water absorbed from the soil, and the remainder (only 6 parts) of mineral substances taken up with the water. The gases which are

absorbed by the plant leaves are always abundantly present in the air, and the only thing, therefore, to which the farmer need pay attention is the supply of the water and mineral substances which are to be taken up by the plant roots from the soil.

It is important, then, to remember that plant life depends on the supply of the requisite amount and kind of food and exactly resembles the life of an animal in this respect.

There is nothing which is so commonly lost sight of as this simple fact. No one would attempt to keep sheep or cattle on a piece of bare dry land, unless grass and water were to be supplied to them. If this were not done, they would of course die of starvation. In precisely the same way plants sprung from seed sown in dry barren land perish from starvation, unless the food which they require be supplied to them in the shape of water and manure.

But there is this important difference between keeping cattle and producing crops, that while the *whole* of the food required by the cattle must be supplied to them, plants need to be supplied with only a small part of the food which they require. If this be given them they are able to provide themselves with the rest from the air, but unless this is given them they perish.

Lesson VII.

The three chief requisites for successful cultivation.

(1) *Good Seed.*

In the preceding lessons a short description has been given of the different parts of plants and

of the functions which they perform in bringing about growth and the production of seed. The object of agriculture is to assist plants to grow well or to bring forth good and plentiful seed, and we shall now be better able to understand the way in which the different operations of agriculture are useful to this end.

Supposing the land which is to be cultivated is not altogether barren or useless, the three things which are required in order to raise a good crop on it are—*firstly*, good seed; *secondly*, sufficient water and manure; and *thirdly*, good tilling and weeding.

First, then, let us consider the *seed*. Improvement may be made in seed in two ways: *firstly*, if the seed is of the ordinary kinds usually sown, such as wheat or maize, care should be taken to ensure its being of the very best and finest quality obtainable; and *secondly*, efforts should also be made to cultivate any new kinds of crops which have been proved to do well and give good profits in India, although they may not as yet have been generally cultivated.

Cultivators seem to be in general but little sensible of the advantage of getting the best possible seed for their sowings. Too often they prefer to sow any seed they have by them, the produce of their own fields, to spending a little money in the purchase of better kinds, although the more valuable crops which the latter would produce would repay them many times over for their outlay in buying it. Most cultivators could obtain better seed than that they usually sow at any of the ordinary village fairs, but as a rule they do

not take the trouble to do so. For this reason good kinds of wheat, maize and other crops are often found to be only grown in one particular village, although frequently there can be no reason why they should not be grown in the other villages near, if cultivators would only take the trouble to purchase some seed instead of always keeping to that grown round their own home. The village of Jaláli, in the Aligarh district, is well known for its fine white wheat. So is the village of Sánkni, in the Bulandshahr district, for its safflower; and many other instances could be given. The cultivation of these good kinds of crops is confined to these villages merely because they happen to have good seed, and not because the soil is much better than in the villages near them.

In European countries far greater attention is paid to procuring good seed than is ever the case in India. People are willing to pay much higher prices for seed grain than they pay for grain to be used as food, and in consequence the production of first class seed for sowing purposes has become a distinct trade, and many farmers confine their attention entirely to this, selling the seed which they produce to the other farmers round them. And quite apart from the undoubted advantage of procuring good seed, even if it costs a little more to do so, there appears to be in some cases great benefit from changing seed, *i.e.*, using seed which has been obtained from some other farm and not grown on one's own land. It is a fact that almost every kind of crop is found to deteriorate if grown year after year from seed produced on the same land as that on which it is cultivated.

Many plants will only grow well from seed which is obtained from elsewhere. Thus the most successful indigo-planters in Behar get their indigo seed each year from districts north-west of Allahabad, since it has been found that seed imported in this way gives far better crops there than that grown on the spot. So general has the practice become that the export of indigo seed from Cawnpore to other towns in Bengal has become an important trade of itself, amounting to over 1¼ lakhs of maunds each year. This is, no doubt, very extraordinary, for at first sight it would seem probable that the best seed for every place would be that produced there, which is used to the soil and climate. But the contrary is found to be the case with many other things besides indigo. For instance, the cotton produced at Hinganghát, in the Central Provinces, is perhaps the best in India and sells at Rs. 22 a maund, while the price of that usually grown in the North-Western Provinces is only about Rs. 17. If seed be obtained from Hinganghát and sown in these provinces, it produces a good and valuable crop the first year; but if the seed of that crop be used as sowing for the next year, the crops then produced will be very little better than the ordinary cotton of the provinces. So that, if the people of these provinces wish to produce cotton like that grown in Hinganghát, they will have to get seed from Hinganghát each year. This at first sight seems difficult, but is not really so. If people wished for Hinganghát cotton seed, there would be a trade in it, and it would be imported in large quantities each year, just as indigo seed is now sent to Behar,

But even if a cultivator is unwilling to incur expense in purchasing seed, and prefers to use that which was produced in his own fields, he should at all events take great care to select the best of his own, and he should remember that it is far more profitable to keep his finest produce for sowing than to sell it at the market rates. He should carefully set aside the largest ears of wheat and the best grown *buttas* of maize. People do not knew what very great improvements may be made in crops by a habit of careful selection like this. Not only may wonderful improvements be made in the size and quality of any kind of grain, but in this way new kinds of grain, fruits, and flowers may, as it were, be created. By a system of selecting seed European vegetables have been brought to great perfection, and European gardeners have doubled the size and beauty of their garden flowers and have often even produced new kinds.

The average weight of a potato is certainly not over a chittack, but by selecting each year the largest ones for seed people have grown them as large as a man's head. The reason why improvements in crops may be made by getting good seed is that the qualities of a plant are more or less hereditary. Indeed, not only are the more important qualities of plants hereditary, but also little differences, which seem at first to be quite accidental. For instance, if in growing the common marigold, one flower by chance should have some white specks on it, and the gardener should carefully put aside the seeds of that flower and sow them separately in the following year, amongst the seedlings which will grow up from

them there will probably be some which will have rather more white about them than the parent flower. The seed of these is again sown separately, and in a few years a yellow marigold with white stripes, or perhaps one altogether white, may be produced in this way.

When such great differences as this may be brought about by the selection of seed, it is evident that smaller differences, such as improvements in the size and quality of grain, would result with comparatively little trouble.

In growing seed for sowing purposes the aim should be to produce a crop, each grain of which is of large size, even although the total weight of the crop may be under the average. To produce full-sized grains of corn or bolls of cotton it is absolutely necessary that each plant should receive ample air and light, and with this object crops grown for seed should be sown much thinner than ordinary crops. In England it is the custom to "dibble," as it is called, wheat which is sown for seed: small holes six inches or sometimes a foot apart are made in the ground with a piece of stick, and one or two grains of wheat dropped into each hole. Sown in this way four or five seers of wheat would be sufficient for a pucka bígha of land, and this small amount of seed could easily be carefully cleaned and selected by the *súp* before sowing.

The total weight of wheat crop gained from land sown in this fashion may not be quite as much as if sown in the ordinary manner at the rate of three quarters of a maund to the bígha, But the grains of wheat will be much larger and

heavier, and, if sown in the following year at the rate of 25 or 30 seers to the bigha, will yield a crop vastly superior to the ordinary in amount and quality.

Exactly the same course can be followed with maize, cotton, or any other crop which is grown for the sake of producing good seed, the general rule being, pick out carefully the best seed which you have and sow it *thinly*, so that each plant may stand out separate from those surrounding it. The land used should of course be the best available.

LESSON VIII.

The three chief requisites for successful cultivation.

(1) *Good Seed*—(continued).

WE have seen that, in sowing the crops ordinarily grown in India, care should be taken to use the very best seed procurable. But there are many crops which have not yet been cultivated in India, or in many parts of India, but which would grow well and give profitable results if care were taken. Therefore, besides sowing the best seed possible of the ordinary kinds of crops, a cultivator should be ready to attempt the cultivation of other crops, even though his father or grandfather may not have even heard of them. Because the crops at present grown in India are well suited to the soil and climate, it does not follow that there are not other kinds of crops even better suited, although their cultivation has not yet been attemped. It is often said that in agriculture experience is our best guide, and therefore the crops

now grown in India are probably the best ones possible. But how can any one say whether a crop will succeed or not until he has tried it? There are many crops now grown profitably in India which were never heard of in the country a hundred years ago. Tea is a good example; it is now grown very extensively in the hills which border on these provinces, as well as those in the province of Bengal. In the hill districts of Kumaun and Garhwál it is estimated that over 2,50,000 seers of tea-leaf are now annually produced, and the total value of the tea exported from the whole of India is now nearly a crore and a half of rupees. To show how rapidly the production of tea is increasing since it was first started in the year 1834 by Lord William Bentinck, then Governor-General, it may be stated that in the year 1847 the value of the tea exported from India to Europe was only a little over a lakh of rupees, while in the year 1876 it was over two crores.

Another and more familiar example of the extent to which new plants may succeed in India is the potato. Its cultivation in these provinces is believed to be of comparatively recent date, and it is known not to have been cultivated in Lower Bengal before the year 1784 from the fact that mention of its experimental introduction into the Patna district is made in the records of the Board of Revenue for that year. Its cultivation is now tolerably common, especially in the Hugli district, where it was previously unknown.

Indeed, people are not generally aware how numerous and important are the trees and crops now grown in India which have been introduced

from the outside. Even the tamarind, which appears now to have become a peculiarly Indian tree, is known to have been originally introduced from Africa; while the edible sugarcane, known as *paunda*, as well as carrots, turnips, and onions, are comparative recent introductions. It is a fact, too, that maize and tobacco, now so commonly grown, were originally introduced into this country from America. With such examples in view, it can certainly never be said that it is useless to attempt to introduce new plants into India. In trying to cultivate a new plant, success must not always, or nearly always, be expected. Very many kinds of crops, which at first sight seemed suited to the climate, have been found not to succeed, and it frequently happens that, in order to get a good crop, a new method of cultivation must be adopted, which can only be discovered after numerous and careful trials. Of course no ordinary cultivator can do all this, and for this reason a special department of Agriculture and Commerce has been created by Government, the work of which is to make experiments in new kinds of crops and new implements, and decide as to those which are likely to succeed.

The number of new crops which have as yet been proved to succeed in the North-Western Provinces is not very great, though some of them appear to be of very great use to the country. The chief of these are lucerne, Guinea-grass, and sorgho—all fodder crops—and new varieties of cotton and maize imported from America.

Lucerne is a plant belonging to the same family as peas and gram and forms when cut green an

excellent fodder, especially suited to horses. It is sown in September and if irrigated will yield three or four cuttings during the following cold and hot weather months, the period when green fodder is most difficult to obtain. The plants do not die down at the end of a year, but if kept weeded and watered will last for at least three years, giving three or four crops of fodder each year.

Guinea-grass is a plant very closely resembling the common *patal* or *sarpat* grass. It grows in large tussocks, and since it lives for many years, it drives its roots far down into the ground, and is able therefore to thrive on much scantier irrigation than than the fodder crops now grown in the country. Like lucerne it will yield several crops in the year, and is much more suitable than lucerne for horned cattle. If grown in moist places, such as along the edges of canal distributaries, it will require little or no irrigation.

Sorgho is a plant which is very like the ordinary juar of the country and which, if grown for fodder, yields about the same quantity as juar. But it differs from juar in containing a great deal of sugar in its stems, and is therefore much more nourishing as cattle food. So large is the quantity of sugar it contains that it is in some countries grown for the sake of the sugar extracted from it, like sugarcane, and it is possible that it might succeed well in India if grown on this account. Another point of difference between it and juar is that its grain is not fit for human food, and so it can only be grown for cattle fodder.

American cotton differs from that grown in these provinces in having a much longer and

silkier fibre, and is much more valuable in consequence. In appearance the plant more nearly resembles the Indian variety known as *narma* or *manua* than the ordinary *kapás*, and like *narma* it will last for several years, yielding a crop each autumn if the plants are cut down to within six inches of the ground after each crop is cut and occasionally watered during the hot season. In a village named Rawatpur, in the Cawnpore district, a bígha of this cotton produced in one year a crop worth Rs. 35, which is very much in excess of the outturn yielded by *kapás* under the same circumstances.

The *maize* plant is a native of America, whence it was originally introduced into India, and by careful cultivation varieties have been produced in that country which are far superior both in size of grain and in quantity of outturn to any maize grown in India. But American maize does not succeed well in India if grown as a kharif crop, and it requires several years' cultivation before it becomes used to the great heat of the Indian hot weather and rainy months. If sown in September, however, some kinds of American maize will yield an excellent crop in the cold weather, which will be ready for cutting in February, at the time when food is generally scarce. At the Cawnpore Farm in 1880, American maize, grown in the cold weather, yielded a crop of 25 maunds to the bígha. This is far in excess of the outturn which could have been raised from country seed.

There are numerous other plants which could be cultivated with advantage in India, the names

and descriptions of which can be ascertained from the Department of Agriculture and Commerce; but first of all the cultivator had better confine himself to improving as far as possible the ordinary crops of the country, and the object of this lesson is not so much to insist on the advantage of trying new plants as to show that they *can* succeed in these provinces as well as those which have been always cultivated; and hence no one should consider a plant useless simply because it is new, and was not cultivated, or even heard of, by his father or grandfather.

Lesson IX.

The three chief requisites for successful cultivation. (2) *Plant-food.*

Having got goot seed, and thus having provided the crops we wish to grow with good parentage, the next thing to be considered is (as with a child) the nourishment and education of the young plants. Proper *nourishment* is given by growing the seed in good, well-manured and well-watered soil; and *education*, by having this soil well ploughed up, cultivated, and weeded. First, then, of nourishment. We have already seen in Lesson VI. that plants require feeding just as animals do, bnt that a great difference exists between the two, in that animals live entirely on solid or liquid food which they take in by their mouth, while plants live to a great extent on food they get from the air through their leaves in the form of a gas, as well as on the food they suck in by their roots. If, then, an animial is

not given food to eat or drink, it dies at once. A plant can live for a short time on what it can get from the air, even though it be not allowed to take in any food by its roots. For instance, if a seed be sown in fine pure sand (in which there is no nourishment) and be watered with perfectly pure water, not containing in solution any of the things on which a plant can feed, it will continue to grow for a short time, living on the gases contained in the air around its leaves. Very soon, however, it will find this nourishment insufficient, and will wither and die before coming to maturity. If, however, a glass cup be placed over the plant, from the air under which all the nourishing gases have been extracted, the plant will not increase in weight at all and will die almost immediately.

It will greatly assist you to understand the nature of the food a plant requires if we shortly consider the natures of the different things of which the soil and air are composed.

It has always been evident that objects in this world are generally combinations of a number of different things: just as, for instance, a *kachauri* is made up of flour, dál, salt, pepper and carroway seeds. What the things were of which the earth, air, and water of this world are composed was not discovered till about 100 years ago, since they are often so closely united that it was very difficult to separate them. Ancient philosophers used to make various guesses: some said that water, others that fire, was the chief principle in the world; but it has now been shown that all these guesses were wrong, and that really this world is made up of between 60 and 70 different things called *elements*.

Most of the things we ordinarily see, such as wood stone, or water, are made up of two or more of these elements combined with one another; but the elements themselves are simple and are not the result of the mixing of two or more things. Thus a piece of chalk can by different processes be separated into three very different substances—a white metal, a solid substance something resembling charcoal, and a gas; and these three things are all *elements* and cannot be sub-divided. It may seem curious that a gas, which no one can see, should combine with two solid substances to make chalk; but the following example of a somewhat similar combination can be given which every one may observe for himself.

In extracting indigo dye from the leaves of indigo plants, the leaves are all thrown into a vat covered with water and left to soak, by which means the little particles of dye are drawn out from the leaves into the water. But they do not become of the proper blue colour till the water has been well agitated or stirred. The blue colour is given to these dye particles by the combination with them of a gas which is present in, the air, and it is to let this gas get near and touch each of the particles that it is the custom to *beat* or agitate the water in the vat.

A great many of the *elements* are metals, such as iron, gold, tin, or silver. The metals are almost the only elements which can be found tolerably pure; the other elements are seldom found alone and are nearly always mixed with something else, from which they have to be separated. The

dál of which a *kachauri* is made contains at least six of these elements combined with one another.

There are two very curious facts about these elements. The first is that when two or more are properly mixed, the substance which results from their combination is quite different from either of the elements of which it is composed. Thus water is made up of two gases which cannot be even seen when by themselves. The second curious fact is that each of these elements can take three forms: it may become solid, liquid, or a gas, although ordinarily it appears in only one of these forms An example of this is pure sulphur, which is one of the elements. In its ordinary state it is solid; if heated it will melt and become liquid; and if still more heated it will turn to a yellow vapour. In the same way iron can be heated till it becomes liquid; but we are not able to give heat great enough to turn it into vapour, though there is little doubt but that this might be done, and may be done some time or other.

To apply this description of the elements to plant-food. An ordinary plant is composed of —*firstly*, water, which often constitutes as much as nine-tenths of its weight; and *secondly*, of elements which, before being taken by the plant, are some solid and others gaseous, but which combine with one another in the plant and become solid or liquid in doing so. The water is taken up from the soil by the plant-roots; the other elements, solid and gaseous, are partly absorbed from the air and partly drawn up by the roots from

the soil together with the water they are dissolved in.

The elements which the plant obtains from the air are always present in the air, and no cultivator can do anything to increase or alter them. All that the cultivator can do is concerned with the supply of water and of the elements which the plant has to obtain from the soil.

Water is necessary for two reasons: in the *first* place it is needed for its own sake, to make up a great part of the weight of the plant; and in the *second* place it is wanted as a carrier for the solid elements which must be dissolved in it before the plant-roots can take them up. If a sponge be placed on a heap of dry salt it will not absorb any part of it, but if the salt be mixed with water the sponge will be able to suck it up. And water is not able to carry these solid elements into the roots unless they are in very small pieces, so as to be able to pass through the tiny holes in the skin which covers the rootlets.

With respect, then, to the food on which crops are to feed, attention must be paid by the cultivator to three points: *firstly*, he must see that all the elements for obtaining which the plant relies on the soil are present in the soil: *secondly*, these elements must be in such small particles as to be dissolved in water; and *thirdly*, there must be sufficient water for the plant to absorb and expand on, as well as to mix with the solid elements and carry them up through the roots.

Lesson X.

The three requisites for successful cultivation.

(2) *Plant-food.*

First Rule.—The solid elements needed by the plant must be present in the soil.

Every one knows that there are very different kinds of soils, varying from the rich land, which can give two or even three good crops a year to the *usar* plain, which will hardly bear a single tuft of grass. Now rich land differs from *usar* in that it has *all* the elements required for plant-food in proper quantity, while the *usar* has only *some* of them.

A plant cannot do without any part of its usual food and cannot replace any missing part with something else. A man who has always lived on cakes of wheat-flour and *mung* pulse, flavoured with Lahori salt, will live almost as well on cakes of millet, *arhar*, pulse, and Sambhar salt, if obliged to do so. But a plant must have each of and all of the kinds of its proper food, or it cannot thrive. Rich land bears such good crops because all the necessary elements are in it and in their proper proportion. Those of which the plants want most are in greatest abundance; those of which the plants want but little are there but to a small amount. Now it must not be supposed that even *reh* is altogether useless. Plants want some *reh*, and no land could be extremely fertile which had not some *reh* in it; but plants require a very little *reh*, while in the *usar* plain there is a great deal of *reh*, and very little of other things which the plants need more: so that a plant

on a *reh* plain is like a man who has nothing to eat but salt.

Land may be fertile—that is to say, it may possess all the necessary elements, either *naturally* or it may have been made so *by manuring;* but however fertile a field may be naturally, it gradually gives less and less produce, unless it be occasionally manured. The plants eat up either all of some necessary thing, or at all events all that part of it which is in a fine enough state to be taken up by the roots; and in this case the field must either be manured, or so well ploughed and dug that fresh portions of the necessary food-substances may be exposed to the atmosphere and may be made fine by the action of sun, wind, and rain. There are fields in the Ganges *khádir* which have for fifteen years borne alternate crops of sugarcane and rice without once having been manured; but now they are beginning to show signs of poverty, and cultivators have to manure them to get the same magnificent crops.

Thus it is by manure that a cultivator is able to feed his crops in giving them things which they want, but which are not in the soil, and by sufficient manure the most barren fields may be made fertile. Some old brick-fields near the city of Cawnpore were recently well dug and copiously manured with the refuse of municipal latrines buried in trenches. Before this was done the land would not have let for 8 annas an acre; now it has been leased at over Rs. 60 an acre.

In Europe great attention has been paid to the pifferent kinds of manure, and for each kind of soil a manure has been discovered which supplies

exactly the food-substances which is wanting in it. People actually send to America, across the Atlantic Ocean, and fetch in ships the dung of sea-birds, which is found in great heaps by the sea-shore. The expense of bringing it is very great, and its price in Europe comes to over Rs. 4 a maund, but it is much used even at this high price.

Now the following are the chief kinds of manure which are available in India, if people chose to use them : the dung of men and beasts, urine, sweepings, ashes, dead leaves, indigo refuse, green crops ploughed, in *khári* earth or water, and powdered bones. Out of these, in ordinary villages only the four first-named are ever used, and those very scantily and with great imprudence. In the cold weather and hot months cow-dung is all consumed in making fuel-cakes, and although this is a terrible waste of manure, yet in the scarcity of wood it cannot be helped. It is only in the rains that the cow-dung is stored up as manure, and then the storing merely consists in heaping it in one corner of a yard, where it is soaked with the rain or scorched by the sun. This exposure to the sun and rain is bad, because some of the most valuable plant-feeding substances in cow-dung are either soluble in water or liable to be evaporated off by the heat of the sun. Exposure to rain and sun therefore soon occasions the loss of these substances ; the former drain off with the water that falls on the dung-heap, the latter fly off into the air ; so that by the time the dung should be carried to the field, instead of being, as it might be, a most nourishing manure, it is a washed-out and dried-up mixture of comparatively little value. It

known that the water of the village tanks is of more service to crops than ordinary canal or well water, and this is because the tank water contains a certain amount of urine which has filtered down into it. The bitter salt in the water of some wells and in some soils is the product of urine which has been allowed to soak in the ground for a long time and has mixed with other substances and changed to this form.

Wells in which there is *khári*-water* (as water containing this bitter salt is called) nearly always occur close to the sites of old villages or near *kheras*, on which old villages formerly stood, where the ground has been soaked for a long time with the urine of both men and beasts. Good cultivators are well aware of the value of this *khári*-water, and use it very extensively in tobacco cultivation. Often a white salt-like *reh* is seen to come out on old mud walls. If the earth of which the walls are built was taken from an *usar* plain, then this white substance is probably *reh* itself; but very often it is *khári* if the earth of which the walls were built was dug from the village pond, into which a great deal of the urine always filters. In some parts of India *khári*-earth as well as *khári*-water is always used as a manure for tobacco.

But of course the benefit gained from urine in this haphazard way is very small compared with what might be gained if it were collected in a

* "*Khari*," or "bitter," is the term applied in some parts of the N.-W. P. to earth and water containing certain fertilizing salts which make them bitter to the taste, but extremely useful as manure.

systematic manner. If in each stable or cowshed there were a vat in which the urine of horses and cattle was allowed to collect, and from which, after having been allowed to stand for a few days, it could be carried out mixed with earth and spread on the land, the improvement which would be effected in the crops would be very marked.

Ashes and house-sweepings are as a rule used as manure, being heaped on the manure-pile in the corner of the cattle-yard. Dead leaves anywhere near a village are nearly all swept up by the gram-parchers instead of being collected and stored. Even in the cotton-fields all the fallen leaves are swept up by the gram-parchers, and the ground is thus robbed of the manure which the plant itself leaves as some payment for the nourishment it has taken from the soil.

Indigo refuse is one of the best manures, but it is only used by the wiser landholders, the imprudent ones burning it in their factory furnaces. It should always if possible be thrown on to the fields, and it is said that much land in the Aligarh district has become ruined by the landholders not doing this, but taking large crops of indigo off their fields with the help of the canal-water, without putting any manure back on to the land.

Another way in which land is often manured in England is by raising a crop of peas and then not gathering the crop, but ploughing it into the ground while green. Plants belonging to the kinds which have long seed-pods, such as peas, gram, indigo, or hemp, take a great deal of nourishment from the air by their leaves and store it up. When

they are ploughed into the ground and covered with earth, the soil gets the advantage of all this nourishment. Some Indian cultivators seem to be dimly aware of this and occasionally grow a crop of hemp in the rains, which is cut down and allowed to rot on the ground at the end of August and then ploughed in as manure. This practice is a most excellent one and cannot be too strongly recommended. The substance which plants of the pod kind extract from the air is the very one which many Indian soils need most sorely, and if the plants are ploughed in, this substance is of course ploughed in with them. The expense is small, being merely the cost of ploughing and sowing and the price of the seed; no rent can be charged against it since the field, being intended for a *rabi* crop, would otherwise have lain fallow during the *kharíf*. To give you an idea of the advantage which results from *green soiling*, as it is termed, in this way the results of two experiments made on the Cawnpore Farm during the year 1880 are quoted. In one experiment a crop of hemp was ploughed in and in the other a crop of indigo. The field manured with hemp yielded seven maunds of wheat to the bígha, while a portion of it which had been left unmanured only yielded four maunds. The field manured with indigo gave still more excellent results, yielding 11 maunds to the bígha, while the unmanured portion only yielded 4½ maunds. Thus we see that the expenditure of, at the most, Rs. 3-8-0 per bígha on a crop of hemp or indigo gave an increase in the outturn amounting in one case to Rs. 6 and in the other to Rs. 13.

Another most excellent manure is the bones of cattle or horses finely ground or powdered. Bones, extraordinary though it may seem, contain a substance which is especially necessary for the grain of wheat, barley, maize, or indeed of any grain crop ; and one reason why certain soils yield crops with a great deal of *bhusa*, but very little grain, is because they are deficient in this substance. The bones should be ground as fine as possible in the lever mill called *dhekoli* worked by three coolies, and the preparation of a maund of bone-dust in this way should not cost more than 12 annas. The bone-dust should be mixed with earth and spread on the land at the rate of 2½ maunds to the bígha, and under cerain circumstances will be found to add enormously to the produce. But since the plant-food contained in bones mixes with water very slowly, and until it is mixed with water the plant roots cannot absorb it, these good results must not be expected until after a year or eighteen months. Bone-dust when applied in this way to a crop of rice on the Cawnpore Farm increased the produce from 6 maunds to 8 maunds per bígha, and taking the increase in straw into account added Rs. 5 to the value to the outturn. Deducting Rs. 2 as the cost of the bone-dust, a net profit remains of Rs. 3.

The plant-food in bone-dust can be made to mix far more quickly with water if the bones be rotted in sulphuric acid. But this is an expensive process in India from the high cost of the acid, and is not therefore recommended. In England sulphuric acid is cheap, and bones are

generally treated with it before being used as manure. The bones are ground and then gradually mixed with the acid in the proportion of two parts of bones to one part of acid, and are then left to stand for two or three days, when they are found to have become quite soft, like white paste, and to mix very readily with water. When applied to the land in this form they give far quicker results than ordinary bone-dust.

It must be remembered that these manures do not all supply the same plant-food; some supply one substance which plants require and others another substance. The plant-food, for instance, yielded by crushed bone is of a totally different character from what yielded by dung, urine, green soiling or *khári* water; while the plant-food yielded by ashes of either dung or vegetable matter is also different from that yielded by bones or by any of the manures last mentioned. In applying manures, therefore, it must be carefully borne in mind that only that manure need be applied to the soil which affords the particular plant-foods in which that soil is deficient. For instance, the rich land of the Tarái abounds in the plant-foods contained in dung, urine, or green crops, and the application of any of these as manures will give little or no advantage. On the other hand it is generally deficient in the plant-food yielded by bones or even lime, and therefore the application of ground bones or lime may give excellent results. The soil of the Doáb, on the other hand, chiefly lacks the plant-food contained in dung, urine, green crops, and *khári* water, and therefore it is these manures which are most advantageous. Another

important fact about manures is that the application of any one plant-food only produces its full effect when there is a sufficient store of all other plant-foods in the soil. If, for instance, a soil is deficient in the plant-food which crushed bones contain and also in that contained by dung, the application of either of these manures separately will give but poor results compared with what may be obtained if both are applied together. On such land the use of crushed bones alone may give an increase of two maunds to the bígha, while the use of dung alone may give an increase of 4 maunds. But if both crushed bones and dung be applied together, the increase will not be 6 maunds, but 10 or 12. If, therefore, the application of any kind of manure to a field does not add much to the outturn, this may be due to two causes: either the soil is well supplied with the particular kind of plant-food yielded by the manure, or it is very deficient in some other plant-food which must be also supplied before the manure can exert its full power. If, for instance, the application of two maunds of bone-dust to an acre of grounds adds but little to the outturn, it may be concluded that either the soil already contains the plant-food yielded by bones, or that it is greatly deficient in some other plant-food. Before deciding, therefore, that the bone-dust is useless, it will be well to apply some dung in company with it, or to manure the field by green soiling before the bones are applied. If after this the use of bones still shows no benefit, then it may be finally concluded that they are not required by the soil.

We see, then, that not only Indian cultivators do not use properly the manures with which they are acquainted, but that there are many kinds of manure of the value of which they are quite ignorant and the use of which may be expected to add very largely to the produce of the land. The waste of cattle-urine and of bones is particularly objectionable, since they are the most valuable manures available to the ordinary cultivator, although he makes little or no use of them.

Lesson XII.

The three requisites for successful cultivation.

(2) *Plant-food.*

Second Rule.—The elements wanted by the plant must be in very minute particles, so as to dissolve in water.

We have seen that a field in order to be fertile must possess all the different elements required by the crop that is to be grown in it, and, moreover, must have them as nearly as possible in the proportion in which they are required. But since the only way the plant can feed on these substances is through its root, it is further necessary that they should be in very fine minute particles, so as to dissolve in water and be absorbed from the soil with it. So long as they are in large hard blocks, they are practically as useless to the plant as if they were not there at all. A man might starve with a cake in his hand if he were not allowed to eat it otherwise than by swallowing it whole.

A great portion of the soil which covers the surface of all cultivable ground was once hard rock or stone, on which no plant could grow. A

fertile soil often only differs from the hard rock from which it was formed in consisting of a vast number of separate particles insted of being one hard lump, and this difference of condition is sufficient to change a barren substance into one extremely fertile. The process by which soils are formed from rocks and stones is always going on. The hard rocks and stones on the earth are always being slowly reduced to fine powder or dust by the influence of the heat of the sun or great cold and rain. Large masses of rock are by these means slowly worn away or split up, and thus it is that on the most barren rocky hills, first a few small mosses or grasses spring up; these are succeeded by low shrubs, the roots of which can live in very shallow soil; and lastly, sufficient soil is formed to grow fine trees or good crops of corn.

The same forces which have created this soil out of hard rock continue to make it finer and finer by dividing its particles, if they are properly exposed to the air. The most powerful force in splitting up rocks is extreme cold. If a thin glass bottle be filled with water and the water frozen to ice, the bottle will burst, since ice takes up more room than water. If, then, rocks be first saturated with rain and then frozen, they are split open in exactly the same way as the bottle. In India there is very seldom frost enough to cause this, and the two forces which do most in dividing up the masses of soil are the heat of the sun, which cracks them, and rain, which slowly melts them away. Since, then, the heat of the sun and the washing of rain are so advantageous to the soil, it is important that as

much of the soil as possible should be exposed to them. As long as the ground is hard and caked either heat or rain can do but little, since only the upper surface is exposed to them. If, however, the ground be first of all loosened by digging or ploughing, the heat and rain can penetrate deep into the ground and can do their work all through it instead of only at the top. Careful cultivators know this, and after the *rabi* crop has been cut give their fields a watering and plough them up, so that the hot winds may blow over loose soil instead of a hard caked surface, and may therefore be better able to split up its particles.

One of the principal uses of ploughing land is, then, to break up the soil into small fragments and render the plant-food which it contains available for absorption by the plant roots. Ploughing brings this about in two ways: in the first place by opening up the soil it enables the air and rain-water to circulate round the soil particles and produce their full effect in splitting them up into smaller pieces; and in the second place it subdivides the soil particles itself by the cutting and grinding action of the plough. Ploughing land enables the air and rain-water to break up the soil as well as breaking it up itself.

In Europe the air and water split up the soil particles mainly by the action of frost, and the land is therefore ploughed up and exposed before the cold weather. But in India heat is the chief agent, and ploughing up for an "open fallow," as it is termed, is most efficacious if performed before the hot weather. Crops of cotton, millets, and pulses are very much benefited if the land be

THE CAWNPORE EARTH-TURNING PLOUGH.

ploughed up two months before they are sown and allowed to lie fallow during the hot months of May and June. A fine subdivision of the soil is even more necessary for rabi than for kharíf crops, and hence it is very important that the ploughing up of land for rabi crops should commence as soon as possible after the kharíf crops have been sown. It is evident that, when land is thus ploughed up to be exposed to the action of air and rain-water, it is important that as much soil should be exposed as possible; or, in other words, that the ploughing should be a deep and not a shallow one. Deep ploughing is only possible with the native plough by driving it over the land a great number of times. This is actually done in the case of *rabi* crops, fields being often ploughed and reploughed as often as 12 or 15 times during the months of July, August, September, and October.

But there is seldom sufficient time to allow of this being done for *kharíf* crops, since it is necessary that many of them be sown as soon after the rains as possible. It is plain, therefore, that an implement which would do in one ploughing what the native plough does in 12 ploughings would be a great benefit to the country. The earth-turning plough, such as is now used in all European countries, is just such an implement. A picture of the kind which appears best suited to India is given on the opposite page. You will see that the body of this plough consists of a flat broad share which cuts the soil 5 inches below the surface and a curved breast which turns the slice of earth cut by the share right over: so that the earth which was 5 inches beneath the surface comes uppermost, and

the whole soil to that depth is quite loose. The Indian plough does not turn over the soil at all, but merely scrapes a little trench in it. The earth which was at the surface remains on the top, merely being pushed up on each side of the share, and the furrow, which may be $2\frac{1}{2}$ inches broad at the top, dwindles into a point at the bottom, since the share is pointed. It may be said, then, that the Indian plough only moves the soil to the depth of $2\frac{1}{2}$ inches, since below that depth the furrows are quite narrow; and though at the surface their edges may touch one another, yet the bottoms are wide apart, unless the field is ploughed over and over again 8 or 10 times, instead of once only, as is the practice in Europe; but even then soil is not *turned over* at all. The European plough, then, is of great advantage, since it loosens so much more soil and exposes it so much more effectually to the heat and rain. But besides this it brings up to the snrface new soil, the elements of which have not been consumed by crops, and thus a single ploughing with a European plough is often equal to manuring a field.

Its good effects, however, are sometimes not seen for two or three years, since the new soil needs some exposure to heat and rain before it can yield good crops.

We see, therefore, that if a field contains the substances which plants require, the best thing we can do is to expose these substances as much as possible to the influences of heat and rain, and we do this best by keeping the soil as loose as possible to as great a depth as we can. Whenever the land lies fallow or without a crop,

as is nearly always the case in April and May, it is always advisable to water and plough it, so that the hot winds of these months may find the soil open and may be able more thoroughly to split up and crumble it. There is no doubt that in some cases deep ploughing may do harm—namely, in fields where the natural soil is actually bad, and the good soil is only a crust two or three inches deep, the result of constant surface manuring. Deep ploughing brings the natural soil of the field to the surface and buries the upper crust with the manure it contains.

The real benefit which, as a rule, results from deep ploughing is proved by the fact that gardeners who wish to raise very heavy crops on a small area always dig up the soil with mattocks to the depth of six or eight inches. This is very expensive if it has to be done by hired labour; but the effect of the English plough is very much the same as this, and its share digs up and turns over the earth very much as a mattock does.

We have seen therefore that for the purpose of exposing the soil to the action of air and rain the soil-turning plough is far superior to the native plough of the country. Ploughing, however, is meant to break up the soil itself as well as allow the air and rain to do so, and for this purpose repeated ploughings with the native plough is probably as good a process as can well be devised. But here again a great saving of time and trouble may be effected by using the earth-turning plough. If the ground be first of all once ploughed up with it and then run over twice or three times with

the native plough, the soil will be as finely powdered as if the native plough had been used 12 or 15 times.

LESSON XIII.

The three requisites for successful cultivation.

(2) *Plant-food.*

THIRD RULE.—There must be water to dissolve the particles of the necessary food substances.

WATER is necessary to plants for two reasons: in the *first* place a very large portion of the plant is actually made up of water; and in the *second* place the roots can only absorb the food substances contained in the soil when they are dissolved in water. Thus water is needed by a plant on its own account as well as on account of the substances it contains.

It is at first difficult to believe how so large a part of ordinary plants consists of water which under great heat may be driven off in the form of steam. Nearly four-fifths of the weight of green wheat, first beginning to flower, consists of water. Nine-tenths of the weight of a cabbage is due to the water it contains; while even the dry straw of wheat and barley contains nearly one-sixth of its weight of water. This is discovered by first of all weighing some of the plant just as it is when reaped or gathered, then drying it in great heat and weighing it again. The great heat drives the water off, and the difference of weight shows the amount of water which was contained. But water is equally important to plants as a carrier of the substances on which

they feed, and which, unless dissolved in water could not be taken up by the roots at all. The water carries these substances up the stem into the leaves, where they are digested, and the surplus water being evaporated off, the remainder finds its way into the different parts of the plant which needs nourishment.

We thus see that the importance which cultivators attach to water is not exaggerated, for it is donbly necessary to plants. It often makes up itself nine-tenths of their weight, and without it a great part of the remaining one-tenth could never be taken up from the soil.

In Europe, as a rule, the rainfall is sufficient irrigation for the fields, and cultivators are not put to the trouble and expense of watering like the cultivators of this country. This is all the more curious because the amcunt of rain which falls during a year in many parts of England, is nearly exactly the same as that which falls in many parts of India (30 inches) ; yet in England this amount is found sufficient, while in India it requires to be supplemented by artificial waterings, at any rate for the more valuable crops of the spring harvest. One reason, no doubt, is the greater heat of India, which evaporates the water more quickly from the ground ; but the chief cause of the difference is that in England the rainfall is distributed somewhat evenly throughout the year, some rain falling in every month, while in India it is all crowded into three months, the remaining nine being absolutely or nearly without any at all. Since, however, 30 incehes of rain are found sufficient in

England, they will be sufficient in India if they can only be kept in the soil till wanted and prevented from being too quickly evaporated by the heat of the sun. If this could only be done, much of the irrigation from canals and wells would be rendered needless.

The soil loses the rain-water which falls on it in two ways: the water either runs away off the surface at once without sinking into the ground at all, or, if it sinks in, it does not go deep enough and is evaporated away by the heat of the sun.

In the first way an enormous quantity of water is lost to the soil, because at the time the rains fall the ground is extremely hard—so hard, indeed, that the rain-water takes a long time to soak into it. Instead of being drunk up by the earth at once, it accumulates on the surface and runs away in channels or water-courses into the great rivers. It is in this way that great floods occur, which sometimes cover a part of the country with water to a depth of many feet, destroying all the crops and houses and causing the death of many men and animals. In no part of the North-Western Provinces, except just under the Himálayan mountains, does more than 48 inches of rain fall in the year. This means that if all the rain stayed where it fell and none sank into the ground or flowed away, the country would be covered with water to the depth of 48 inches. But in these floods water often rises to three times this depth, because, besides the water which has fallen at that place, other water has come from other places.

It should be the object of every good cultivator, therefore, to ensure as far as possible all the rain

which falls on his land sinking in at once and not running away elsewhere. This can be done by making *bands* round the fields to stop the water from draining away, and also by keeping the surface of the ground soft, so that the rain will sink into it directly it falls on to it.

But a great portion of the rain-water which *does* sink into the soil is afterwards lost by evaporation. The best method of preventing this is to keep the surface soil loose and not allow it to become hard and caked. At first sight it would seem that the opposite of this would be the case, and that the moisture in the soil would be less likely to evaporate when there was a crust of hard earth above it than when it was only protected from the sun's heat by a layer of loose mould. But fine earth, when tightly packed, as, for instance, a sun-burnt brick, soaks up water more quickly than when it is in a loose condition ; so that when the surface of the ground is hard, it keeps soaking up the moisture from below and exposing it to the heat of the sun, while loose earth cannot absorb it in this way, and therefore leaves it below it protected from the direct action of the heat. It is well known that trees will often die of drought in the hot weather, unless the soil above their roots is kept loose, and to dig up the surface soil of a mango grove is one of the surest ways of preventing the fruit from drying up in the hot winds and falling off prematurely in a shrivelled condition.

Cultivators who take the trouble to water and plough up their fields after their crop has been cut, even although the land will not be resown for six

months, are therefore benefited by the less amount of moisture their land loses by evaporation and by the greater amount of water which it will absorb when the rain falls, as well as by the splitting up of the soil under the hot winds which has been noticed before. When possible, lands should always be ploughed up before the rain falls, so as to act like a sponge and soak it up quickly. An excellent illustration of the advantage which results from allowing the rain to fall on ploughed instead of on unploughed land is afforded by a crop of wheat gathered on the Cawnpore Farm in the rabi season of 1881. The preceding kharif had been one of great drought, the rainfall only amounting to $\frac{1}{6}$th of the average. A portion of a field was ploughed with the earth-turning plough at the commencement of the rainy season in July, while the remainder was left unploughed till the end of the rains in September. The little rain which fell was all absorbed at once on the ploughed-up portion, while on the unploughed portion it was absorbed more slowly, and much was lost either by evaporation or by running off the surface. In October both portions were ploughed up and sown with wheat. The portion which was ploughed up in July gave an outturn of 10 maunds of grain to the bigha, while the other only yielded 6 maunds. *Early ploughing in this case made a difference of Rs. 11 in the profits per bigha.*

It is evident that the earth-turning plough is very much more useful in opening the soil, so as to absorb the rainfall, than the native implement. The trampling of the bullocks in

ploughing year after year and the rubbing of the plough-share have made in most fields a hard layer of tightly pressed earth 2½ or 3 inches below the surface. The rain-water cannot penetrate it, and although the water may rapidly soak into the 2½ inches of soft soil, it cannot sink quickly down further than this. The result is that, instead of the soil to the depth of 2 feet being properly saturated with moisture, there is a sloppy marsh of mud and water to the depth of 2½ inches, while below that the earth is as hard as ever. The moisture, being only to the depth of 2½ or 3 inches, is fully exposed to the fierce heat of the sun and is evaporated off in a few days, leaving the mud behind caked into a mass as hard as stone.

Of course it would be quite possible to remedy this state of things and open up the soil to a greater depth by driving the native plough over a field a great many number of times. But this takes a long time, and at the periods when ploughing is possible no time can be spared. And besides this, the repeated pressure of the bullocks' feet and of the plough-sole has a tendency to harden the soil a few inches below the surface and counteract to some extent the loosening effect of the ploughing. The earth-turning plough, however, in one ploughing will break up and open out the soil to a depth of 5 or 6 inches, and with a pair of fairly good bullocks a bigha of land can be ploughed in this manner in one day. The advantages which result from this deep ploughing have been proved by numerous and careful experiments in all parts of India, and are especially noticeable

in a year of deficient rainfall. On the Cawnpore Farm during the kharíf of 1880 (which has already been mentioned as a season of great drought) unirrigated fields which had been cultivated with the earth-turning plough gave an outturn of two maunds of clean cotton to the bígha, whole fields cultivated in the native manner only yielded one maund. There was therefore a difference in value of at least Rs. 16 per bígha.

The adoption of the earth-turning plough by native cultivators is therefore very much to be desired. Two objections are, however, commonly made by them to it: firstly, that it is so heavy that the small bullocks of the country cannot draw it; and secondly, that it costs so much that they cannot afford to buy it.

The earth-turning plough is undoubtedly harder to draw than most native ploughs, as indeed must follow from the far larger amount of work that it does. But the increase in weight is not at all in proportion to the increase in work, and it may be safely said that a plough constructed on the native system and intended to do as much work as the earth-turning plough would be at least twice as difficult to draw. Such a plough actually exists in the *Nágar* of Bundelkhand, which ploughs 9 inches deep and is drawn by four pairs of bullocks. An earth-turning plough could be made to do this easily if worked by two pairs, since it cuts the soil instead of tearing it, and therefore travels lighter. But the light ploughs now made at Cawnpore under the Department of Agriculture and Commerce, which are meant to plough to a depth of 5 inches, can easily be drawn by a pair

of fairly good bullocks; and if none but the smallest bullocks are available, it will be found profitable to work it with two pairs, since one ploughing in this way will be more effectual than three ploughings with each pair using the native plough.

A good earth-turning plough can now be procured for Rs. 6 or 7, and there are very few cultivators who cannot afford to give this for an implement which will last two or three years, and will often more than pay for its price in the first season by the increase in crops which will follow on its use.

Lesson XIV.

The three requisites for successful cultivation.

(2) *Plant-food.*

Third Rule (continued.)—There must be water to dissolve the particles of the necessary food substances.

We have explained the reason why as a rule the rain which falls in India is not sufficient watering for the more valuable kinds of spring-crops, such as wheat, and we have seen how deeper ploughing may probably remedy this. But, fortunately, a great portion of the cultivated land in Upper India is not altogether dependent on the rainfall for its water-supply, but can be irrigated from canals, tanks, or wells.

The total cropped area in the North-West Provinces and Oudh is about 36 millions of acres. Of this nearly one-half could be irrigated if wells were dug wherever possible; but the area actually watered is less than one-third (11 million acres),

the remaining 25 million acres being dependent on the rainfall for their water-supply.

Irrigation may be derived from canals, wells, or other sources, such as rivers and tanks. Out of the total 11 million acres irrigated, canals give water to (roughly) speaking) 1½ million, wells to 5½ millions, while the remaining 4 million acres are watered from other sources.

It is often said that canal-water does harm to land, and it is undoubtedly true that in some cases land has been impoverished and *usar* extended by the use of canal-water. But it has been proved that the harm results not so much from the canal-water itself as from the way in which the cultivators use it. When a man has to water his fields from a well, each drop of water he puts on to it costs a good deal of labour and trouble. But with canal-water the case is different. All that is often necessary is to cut a hole in a bank and the water flows over the land without further trouble. The result is that while only just as much well-water is used as is absolutely necessary, as much canal-water is let on to the field as can be got, and the land becomes *swamped* instead of irrigated. As has been mentioned before, the native plough only loosens the soil to a little depth, below which there is a hard layer of earth. The water therefore does not sink right down into the earth, but merely makes the field a slough of mud and water to the depth of some 2½ inches, and lies till it is dried up by the heat of the sun, when it leaves the earth caked and as hard as a brick. Indeed, bricks are made much in this manner. Whatever salt or

reh there may be in the ground is dissolved by the water, and as the water dries up is brought to the surface with it, making the land quite barren. Every one knows that it is after a good fall of rain that *reh* comes to the surface most abundantly.

An excess of water is also harmful because it makes the land cold, since when it evaporates it draws the heat of land away with it. Hence we see that *too much* water cakes the ground, draws *reh* to the surface, and chills the soil. When canal-water is available it is generally used in excess, and hence it is that cultivators blame canal-water when it is only their own way of using it which should really be found fault with.

The indiscriminate use of canal-water may harm the land in another way. People often irrigate with canal-water land which it would not pay to irrigate from a well unless it were first manured. They use water instead of manure, forgetting that, though water may constitute nine-tenths of the plant, it is useless without the other one-tenth—that is to say, the food substances which should be present in the soil and which it can dissolve, but for which it cannot act as substitute.

At the outset magnificent crops are often obtained from land which was previously unirrigated, but to which canal irrigation has been extended, though no manure is used. The food substances of the soil had from lack of water been but little dissolved, and therefore but little consumed by the crops. A more plentiful supply of water dissolves more of these substances, and more of them become available as plant-foot, giving a

larger crop in consequence. But it must not be forgotten that the water has not *added* anything to the land, and in reality actually impoverishes it for succeeding years. It is as if a man, to whom a monthly allowance of 15 seers of flour is given, were to eat it all up in the first 15 days instead of keeping to ½ seer a day for the whole 30 days. Though at first he may thrive extraordinarily, yet when the flour fails and he is only half way through the month, he will be worse off than if he had contented himself with a more moderate allowance.

Land becomes poor when a large proportion of the food substances which it once possessed have been eaten up by successive crops. A light watering from a well would not be able to dissolve the little of them that is left, and if only well-water were available, it would be necessary to manure the ground before growing a crop on it. Or if the field, instead of being cropped, had been left to lie fallow for a year or two, it would have recovered itself, since by the crumbling up of the soil, food substances which were before in too large pieces to be taken up by the plant roots become fined down and soluble in water. Before canals were made, the area irrigated was much smaller than it is now. In those days, when wells were the principal means of irrigation, nearly all the irrigated fields were well manured, since, being few in number, there was sufficient manure for them.

But now the irrigated fields have become more numerous, and there is not sufficient manure for them all. A great portion of them is therefore

watered without being given any manure at all, or in anything like proper quantities.

Of course a field which is both watered and manured gives a better crop than one which is watered but not manured. Land watered from a well is nearly always manured, but a great deal of that watered from canals is not manured; and hence the *average* outturn from canal-irrigated land may bo less than that of well-irrigated land without its being any fault whatever of the canal-water.

It has been pointed out before that the system of watering without manuring not only gives less crops than watering with manuring, but also in time may impoverish the land. The water enables the crops to eat up more food substances than can be prepared for them during the year by the action of the sun, rain and air on the soil, and the plants are therefore like a man who eats up his whole month's allowance of food in fifteen days and has to starve for the remainder.

We have thus seen that most of the faults which people attribute to canal-water are really only faults in the way it is used. To see the wonderful advantages which canal-irrigation gives, one should look at the fields in a year in which the rains fail, such as 1877. In that year in most districts the kharif crops entirely failed on all fields which depended on rain for their watering, and many of the wells dried up, so that crops which depended on them mostly failed in addition. But in those parts where canal-water was obtainable crops flourished as usual, and the zemindars in consequence made very great profits.

The harm that an over-supply of canal-water does can be greatly lessened by deep ploughing or draining. Deep ploughing loosens the soil to a greater depth, and so enables the ground to absorb more of the water instead of keeping it lying on the surface till evaporated by the sun's heat.

Draining acts in much the same way, but is too expensive to be much used in India. The following is the way in which land is drained in England:—Parellel trenches are dug about 4 feet deep and at intervals of 8 yards, right across the fields, all sloping in one direction towards a ditch, pond, or river, which can carry off the surplus water. In these trenches are laid pipes of burnt clay about 3 inches in diameter and 2 feet long, and joined end to end by collars so as to make one long pipe running down each trench. The pipes are covered in with earth and the ground levelled off as before. When there is any surplus water in the ground as after heavy rain or over-irrigation from a canal, the excess water sinks into the ground through the loosened earth down to the pipes. The pipes are empty, and the water pressing to get inside them trickles through the tiny holes there are always in burnt clay, or filters in at the joint of the pipes and flows down them into the pond or river towards which they slope.

By this process, instead of the water mixing with the upper soil, rendering it sloppy, and then evaporating off, bringing the salts and *reh* up to the top with it, it keeps soaking down through the soil and runs off from below the surface: it does not make the ground too wet, because it is carried off by the pipes before it can do this, and instead

of bringing the salts to the top it keeps carrying them down, since the pipes do the work of the sun and carry off the extra water instead of letting it rise to the surface and evaporate there. If this could be done in India, most *usar* plains could probably be made fertile; but it would cost at least Rs. 100 an acre, and this very few landlords would care to expend.

There is one way, however, in which much good can be done to *usar* land at a very little expense. In the cold weather, before the rains begin, shallow trenches should be dug or scooped right across the field at about 2 feet apart. These should all slope towards a pit which should be dug in one corner. It is during the heat of April and May that the *reh* chiefly comes to the surface; and when the rain falls, it will dissolve and run down the trenches into the pit. After a month the pit should be closed with earth, and by degrees, in this way, the *reh* can be gradually washed out of *usar* land and the soil be made capable of cultivation. The reason why, unless this be done, *usar* land can never improve is that each year the rain-water carries the *reh* down into the soil with it, and brings it up again when it evaporates, just like the bucket of a well—up and down, up and down.

There can be no doubt that when available well-water is better than canal-water, and cultivators express this in the proverb—*Má ke dudh se kya bihtar*. This is a very true proverb, for the usefulness of the water is due to its containing in solution some of the substances on which plants feed, which it brings up from underneath

the surface, and so gives a fresh supply of the very substances which the crops have been removing.

Thus, tobacco drinks up saltpetre and other *khari* solutions eagerly, and, if there is anything of that kind in the soil, quickly devours it. If there is a *khari* well from which to water it, the thirst of the plant is constantly being satisfied by a fresh supply of its favourite drink and it thrives. If the supply of salts be not renewed, it grows pale and yellow, as you may often have seen.

Not uncommonly cultivators ruin the quality of their well-water by the way in which they carry it to their field. The field may be some little distance from the well, and the water may have to run across a plot of *usar* land. The banks of the channel along which it is conveyed are often made up of earth dug from the *usar* and containing large quantities of *reh*. The well-water, as it passes, dilutes this *reh* and carries it to the field which it is irrigating. In very many cases in which cultivators have complained that *reh* is appearing in their fields, it has been proved that it has been carried with water in this way, although the water itself when first drawn from the well or canal was perfectly pure.

Lesson XV.

The three requisites for successful cultivation.

(3) *Careful Protection.*

We have seen that, in order to obtain a good crop, it is first of all necessary to get good seed,

and then care must be taken to sow this seed in ground where it will find all the substances which are needful for its food; that is to say, in ground which has been well ploughed, well manured (unless naturally fertile), and well watered. But this is not sufficient. Just as a good father is not content with merely feeding his children, but also educates them and keep them from all people or things which may do them harm, so a good cultivator must keep his field clear from weeds, keep it safe from birds or beasts which may harm the crops, and in many cases train the young shoots by pruning or in other ways. The different operations which are needful after the young plants have come up are compared to the education of a boy and form the subject of this lesson.

The importance of proper weeding is so well known that nothing need be said here about it. Weeds feed on the same substances as plants, and a cultivator who does not keep his fields free from them is like a father who allows dogs to eat part of his children's food. Most weeds can be got rid of by hand-picking, but there are some kinds which are much more troublesome, and which, from the length of their roots, it is extremely difficult to eradicade from the land. The *káns* grass, which occurs in Bundelkhand, has made a great deal of country quite uncultivable, since the native plough is unable to tear up its roots, and it is necessary to dig up the whole land with mattocks, at an expense of time, money, or trouble which cultivators rarely like to incur. Deep ploughing with the earth-turning plough

would probably, however, be successful, and has actually been found in the Bánda district to be of great effect in reclaiming land infected with this grass.

But it is not only necessary to uproot weeds if a good crop is wanted ; it is often found useful to thin out the crop itself by pulling up weekly-looking plants and leaving more room for the stronger ones to come to perfection. But weeding a crop in this manner by pulling up some of the plants is to some extent a waste of seed, and if especially fine plants are required, it is well to *sow* less seed than is ordinarily used.

This is especially important when it is wished to produce good seed for sowing purposes, for which it is absolutely necessary that each plant should not be crowded by those around it. The good effect of "dibbling" wheat has been noticed in Lesson VII., and cases have been known of wheat-seed sown in this way producing 220-fold instead of 11-fold, which is the return usually obtained in the country.

Broad-cast sowing is as a rule to be avoided, since however carefully the seed be sown it is impossible to prevent unevenness, and in some places the plants will be unduly crowded, while in others they will be too thin. Great improvement can be effected in many of the crops ordinarily sown broad-cast (such as juar and cotton) if they be sown in lines, leaving at least 6 inches between the lines. Another advantage in sowing in lines instead of broad-cast is the great assistance it gives to weeding. In the North-West Provinces, in sowing indigo, it is the custom to

scatter the seed about the field after watering it and then plough it in with the native plough. This is as bad cultivation as can well be. One ploughing with the native plough does little more than scratch the ground, and does not even tear up the roots of the previous crop. The seed being sown irregularly comes up irregularly, crowded in some places and thin in others. In Behar it is the custom with European indigo-planters to use a machine for sowing indigo, consisting of a box on wheels which is drawn over the field. The seed is placed in the box and runs down on the ground through a row of little pipes fixed in the bottom of the box. By this means the seed is sown in even parallel rows, and the plants come up regularly, each having its proper amount of room. But unless some sort of implement as this be used it is difficult to sow crops like indigo or cotton in lines, since if sown behind the plough, like wheat or maize, they are buried too deeply and do not germinate properly.

In this lesson may be mentioned the method of improving trees by budding or grafting; that is to say, by fixing on to one tree a bud or shoot taken from another. If this be done in the proper way the bud or shoot will go on growing and will fix itself on the tree it is fastened to, and the flower or fruit it bears will be as a rule much better than those which are produced by the tree from which it was taken or by the other branches of the tree to which it is fastened. There are many different ways of budding or grafting which cannot all be described here, and which as

a rule require considerable skill and practice to be successful. It is important to remember that all kinds of trees cannot be budded on to one another, but that the bud must be of the same or nearly the same kind of tree as the one on which it is fixed. If, for instance, a mango bud be fixed on a lime tree, it will die because the trees are quite dissimilar; but if any orange bud be fixed on a lime tree or a rose bud on a briar they will grow, becauee in both cases the trees are nearly alike. Budding is much used to improve the flowers of rose trees, but the chief way in which its practice would be useful to villagers is in the production of good mango trees. If young trees be grown from the seeds of the best Bombay mangoes, the fruit they give will not be nearly as good as that of the parent tree. To get good fruit it is necessary to graft on them. When the seedlings are a year old, they should be carefully dug up in the rains, a small ball of earth being left round the roots, which should be bound round with grass, so as to be prevented from falling off. The seedling should then be slung on to the end of a branch of a Bombay mango tree (or of whatever kind of mango it is desired to make a graft of), its top should be cut off slantingly, a slit cut off one of the shoots of the branch it is slung upon and the shoot tied on to the cut top of the seedling, so as to join them firmly by their faces. They should be tied up with string and a little mud stuck on round the join, so as to prevent the air getting to it. In a short time they will be found to have joined firmly, when the shoot of the tree should be cut off six inches above the join, so as to

leave that length of it fastened to the top of the seedling. The seedling should not be allowed to grow any branches except from the shoot grafted on to it, and all buds coming out from any other place should be carefully picked off.

Lesson XVI.

On agricultural machinery and implements.

In this lesson it is intended to give a short account of a few of the implements or machines which are used in Europe and America for the production or preparation of agricultural crops, pointing out in the case of each one the advantages or disadvantages which it exhibits when used in Indian agriculture.

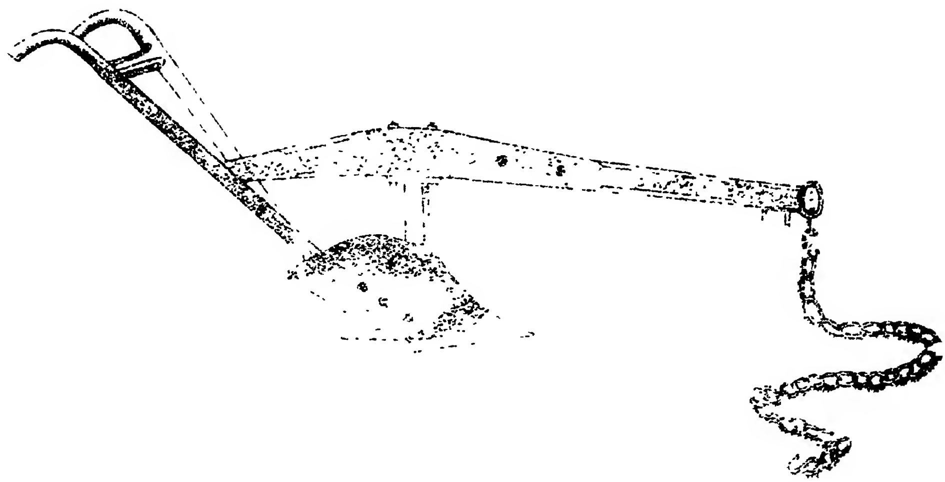
Now in the first place it must be remembered that implements are of two kinds, according (i) as they merely take the place of human or cattle labour and render it possible to perform a work with either fewer men (or cattle) than would otherwise be required or without their aid at all, or (ii) as they enable the performance of a work which without them would be altogether impossible. Implements of the first class are called "labour saving," and a good instance is the windmill, which is a machine which, when worked by the wind, will lift as much water in a day as four or five coolies would be able to do with the basket. On the other hand, a good example of a machine which enables men to do a thing which would otherwise be impossible is the flour-mill for grinding grain into flour.

So far as the labour-saving machine is concerned, it is plain that the cheaper the labour is which will be saved by it, the less advantageous will the

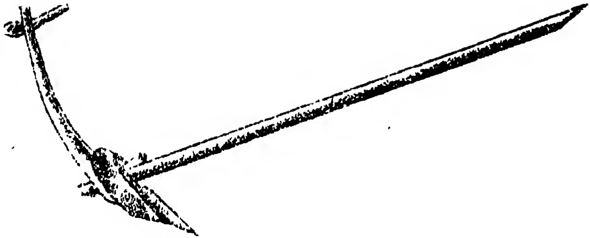
machine be. Labour is extremely cheap in India. In America a farm labourer is paid one rupee eight annas a day; in England he is paid one rupee, while in India he is only paid two annas. Hence we find that America is the country in which labour-saving machinery is most used and India the country in which it is least used. It would be profitable to pay Rs. 540 in America for a machine which would do the work of four men and would thus save Rs. 6 a day, even if the machine would not last more than a year. But in India the saving effected by using this machine would be only 8 annas a day, and it would not, therefore, be profitable to pay more than Rs. 180 for it.

It is evident, therefore, that a large proportion of the machinery used in Europe and America which has for its object the saving of labour is totally unfitted for India. But there are nevertheless some simple implements which enable men to do what would otherwise require a very great amount of time and trouble which might be usefully introduced in India.

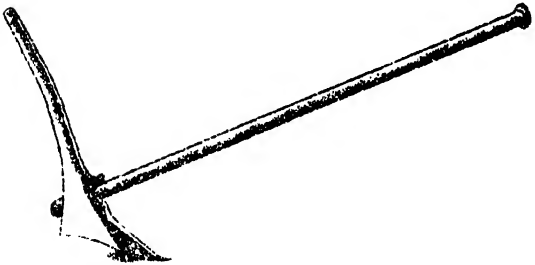
(1) *The earth-turning plough.*—The advantages which result from the use of this plough have been already described in Lessons XII. and XIII. But it must not be imagined that the sketch facing page 53 at all resembles the plough in use in either Europe or America. The plough there figured is one which has been specially altered so as to suit the Indian cultivator, and those used in Europe or America differ from it in many respects; the most important one being that they are not fitted with a long beam reaching to the yoke of the bullocks, but have



THE AMERICAN PLOUGH.



PRESENT NATIVE PLOUGH.



OLD ENGLISH PLOUGH.

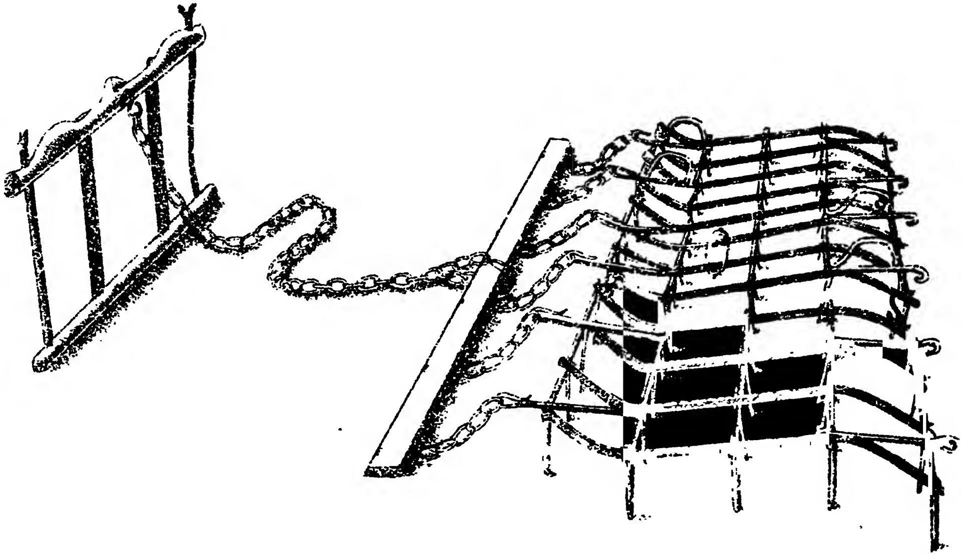
a short beam, as in the illustration, which is fastened to the yoke of the bullocks or the traces of the horses by a chain or rope. This method of attaching the plough has great advantages over the long fixed beam, since the plough is lighter, is more easily managed, and runs more steadily through the soil. But the ploughman is obliged to be at some distance behind his bullocks, and finds it therefore rather more difficult to drive them.

It is an interesting fact that 900 years ago the plough used in England was very similar to that now used in India, and a picture of one of these ancient English ploughs side by side of one of these now used in India is given opposite. If the English plough has so vastly improved, there would appear to be no reason why the Indian plough should not be improved also.

(2) *The harrow.*—The harrow is a wooden or iron frame bearing on the underside a number of iron teeth or pegs, which tear up the soil to a depth of 2 or 2½ inches when the harrow is drawn over it. A sketch of a light harrow is given opposite page 78, and it will be seen that the iron teeth are so placed that no one of them follows any other one in the same line, but that each passes over a different strip of soil when the harrow is drawn over the ground. In Europe the harrow is much used for collecting together weeds and grass which have been uprooted by the plough, and which, if not at once removed, would take root and grow again. It is also used for covering in wheat and other seed which has been sown broad-cast,

and in this way saves a great deal of time and trouble, since, if the harrow is drawn twice over a field, the seed will be covered as completely as if it had been ploughed in with the native plough. Another useful purpose which the harrow might serve in this country is to open the surface soil of fields after the first fall of rain in June or July, and so enable the ground to rapidly absorb any subsequent rainfall. A bígha of ground which it would take a whole day to lay open by ploughing might be opened with a harrow in a couple of hours. In drawing the harrow a single pair or two pairs of bullocks are used according to its size. It is fastened to the bullocks in the same manner as the native clod-crusher (*mai or patela*). The cost of a small harrow suited for a single pair of bullocks would be about Rs. 15, and for a larger one suited for two pairs about Rs. 30.

(3) *The pump for raising water.*—This will of course only be useful in places where it is necessary or advisable to use water for irrigation, and in some cases it will be found that a cheap form of pump will give better results than any of the native methods of lifting water. The principal methods of lifting water used in upper India are the swing basket (*beri* or *bauka*), which can be worked for 10 hours continually by four men; the lever lift (*dhenkli*), which can be worked for 10 hours by two men; and the well bucket (*pur* or *charsa*), which can be worked for 8 hours a day by one pair of bullocks and two men. Each of these lifts is fitted for a different depth: thus the swing basket is only suited for lifting water from a



THE ENGLISH HARROW.

depth of 5 feet or less, the dhenkli from a depth of 8 to 15 feet, and the well bucket from 15 to 40 feet. If each lift is worked at the depth best suited to it, the number of hours which it will take to irrigate an acre and the cost of such irrigation (excluding the cost of the implement itself) will be as follows :—

Name of lift.	Depth from surface of ground to surface of water.	Number of hours in which an acre will be watered.	Cost of such watering.
	Feet.		Rs. a. p.
Swing basket ...	5	21	1 0 0
Dhenkli ...	15	112	2 12 0
Well bucket ...	30	53	5 10 0

It will be seen that the cost of watering an acre of land increases rapidly as the water is farther from the surface.

Each of these lifts is most effective when used at about the depths noted above. If, for instance, it were attempted to raise water from 15 feet by the owing basket instead of the dhenkli, the cost for irrigating an acre would be Rs. 3 instead of Rs. 2-12-0; and if the well bucket were used instead of the dhenkli for a depth of 15 feet, the cost would be Rs. 4-6 per acre instead of Rs. 2-12-0.

For all depths more than 20 or 25 feet it is believed that the well bucket drawn by bullocks is the most effective lift known, taking into consideration the cost of the work done as well as its amount. Of course there are numerous

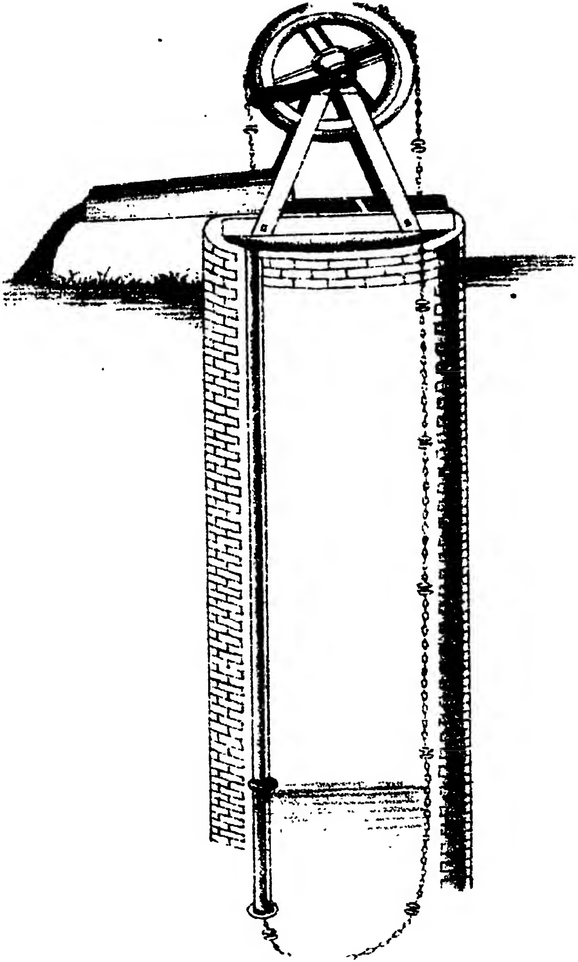
machines which will left six or eight times the amount of water which a well bucket will give, but the cost of the machine is so great that the work done by it is extremely expensive.

There can be no doubt, however, that for depths between 12 feet to 20 feet neither dhenkli nor well bucket are very satisfactory, and for depths between these limits there appears to be some need of a new method of raising water.

The Persian wheel (or *rahat*) used in the Panjáb is found to work well for depths between 12 and 20 feet; but it is a clumsy machine, consisting as it does of two large wooden wheels so fitted into one another that when one wheel is turned round horizontally by a pair of bullocks the other wheel is turned vertically. The water is brought up by a long chain of earthenware or metal jars borne by the vertical wheel and turned round by it.

Another form of lift which appears to be in some respects well suited for this depth is the *double moth,* in which two buckets are used instead of one. The buckets are attached one to each end of a long rope which is twisted round a large horizontal wheel or drum, so that when this drum is turned by a pair of bullocks or a buffalo, one bucket is lowered down empty into the well while the other bucket is brought up full. The buckets too are so constructed as to empty themselves when they reach the top of the well and not to require a man to empty them.

But the form of lift which appears to be most advantageous in every way for depths between 12



and 20 feet is a hand pump of the kind figured on the opposite page. It consists of (i) an iron pipe, one end of which is on a level with the surface of the ground, while the other end is immersed in the water, (ii) a chain running through the pipe bearing plugs or suckers at a distance of every 5 feet, and (iii) a wheel by which the chain is turned round. As the chain is turned, the plugs which are attached to it travel up through the pipe, each bringing up a column of water before it. To save unnecessary friction the plugs only fit tightly into the lower 5 feet of the pipe, which are of rather smaller diameter than the upper portion. The wheel is turned by two coolies, and four men can work the pump for ten hours a day. Its work at a depth of 15 feet is compared below with that of the dhenkli and well bucket:—

	Number of hours in which one acre is watered.	Cost of watering one acre.		
		Rs.	a.	p.
Dhenkli ...	112	2	12	0
Well bucket ...	40	4	6	0
Hand pump ...	31	1	8	0

Not only does it irrigate much more rapidly than either the dhenkli or well bucket, but the cost per acre is considerably less.

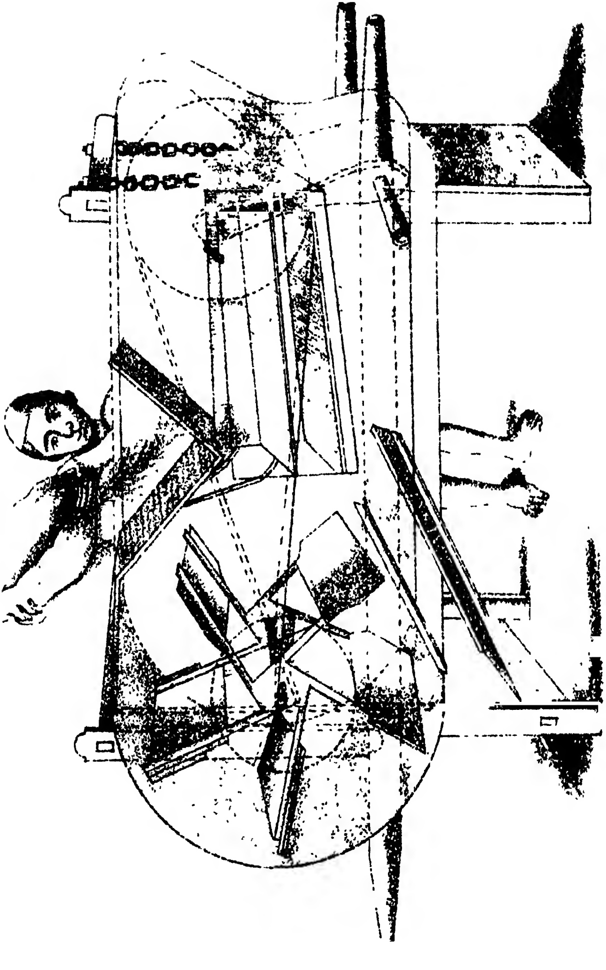
Such a pump as the one described can be obtained for about Rs. 45, so that its cost is considerably less than that of a pair of good bullocks.

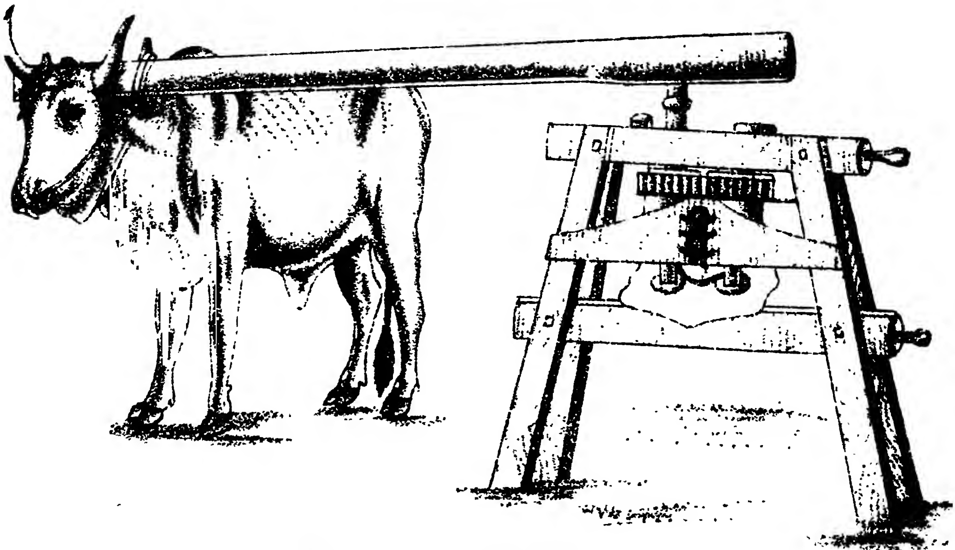
(4) *The winnower for separating the bhusa from the grain of corn which has been thrashed out and also for separating the small grains from the large ones.*—In this country the bhusa is separated from the grain by the simple method of exposure to the wind. A basketful of mixed grain and bhusa is taken and emptied out on to the ground from the height of 3 or 4 feet, and the wind blowing through it as it falls drives the light bhusa to one side, but allow the grain to fall straight down. If a tolerably strong wind is blowing, three men can in this way clean 25 maunds of grain in seven hours.

The wind which is required must be strong enough to blow all the bhusa to one side, but must not be so strong as to blow it away altogether; and it often happens that for two or three weeks there is either no wind at all or too strong a wind, and the grain and bhusa has therefore to be allowed to lie uncleaned in the threshing-floor, exposed to the chance of rain and hail.

When there is no wind and it is necessary to clean the grain in some way or other, cultivators make an artificial breeze by fanning the grain and bhusa with a sheet as they are poured out on the ground. But this is a very tedious and expensive process, six men being able to clean only 15 maunds in a day.

In Europe and America the machine called a winnower is always used to clean the grain after threshing. It consists (see figure opposite) of a revolving fan, in front of which are two or more horizontal sieves of different-sized meshes. The fan is turned by a handle at the side, and at the





THE BIHIA SUGAR-MILL.

same time the sieves are shaken from side to side by a rod connected with the handle. When the mixed grain and bhusa is poured on to the topmost sieve in front of the fan, it drops evenly through the meshes and is thus exposed to the wind which the fan creates. The chaff is all blown away in front, while the grain falls down on to the lower sieve. This sieve is of too small a mesh to allow good-sized grains to pass through it, and it slants backwards, so that the good grain rolls down and falls off its hinder edge into a box or sack placed there to receive it. Small-sized or withered grains, together with any small seeds of a different sort, such as mustard or rape, fall through the meshes of the lower sieve instead of running down of it, and are in this way separated from the good grain.

English-made winnowers cost as much as Rs. 200 in India, but a cheaper though very effective kind is made up in the Government Farm Workshop at Cawnpore which only costs Rs. 35. Working with this two men and a boy clean 24 maunds of wheat grain in a day, whether a wind be blowing or not.

(5) *The roller mill for crushing sugarcane.*—A picture of this is given on the opposite page. It consists of two iron rollers placed side by side in a strong wooden frame, and so fitted together that when one is turned by a long beam from above, the other turns with it, but in an opposite direction. The cane is placed between the rollers—three stalks at a time—and is thoroughly well crushed. If the rollers get loose, so that the cane is not sufficiently well crushed, they can be screwed

tightly together again. Only one bullock is required to work the mill.

Compared with the ordinary country kolhu this roller mill has the following advantages :—

It crushes the cane evenly and does not *grind* it as the kolhu does. In consequence the cane-juice is clean, is free from vegetable acids, and gives clearer and better granulated sugar.

It saves the labour of cutting the canes into strips, since the stalks are put in whole ; and there is also less danger of the juice acidifying, since it is not so much exposed to the air as when the canes are cut into short strips.

It can be worked by two men and one bullock instead of three men, two boys, and two bullocks, which the kolhu requires.

Its price is high—Rs. 90 ; but its advantages have been so much appreciated that over 5,000 have been sold in Behar and 2,000 in these provinces during the last four years, and the sale is rapidly increasing. The mill is the invention of some English landholders in Behar, but can be obtained on application to the Department of Agriculture and Commerce.